AIR FORCE RESEARCH LABORATORY
SUCCESS STORIES

A REVIEW OF
2004

To receive more information about any of the success stories in this book or on the CD-ROM, or for other technical activities in the Air Force Research Laboratory, contact TECH CONNECT at (800) 203-6451.

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AFRL Success Story Program

Helping to maintain the Air Force's strong

Science and Technology foundation

one success at a time.

2004 was a wonderful and exciting year for the Air Force Research Laboratory. As the individual success stories in this volume will attest, our dedicated and highly skilled men and women, in partnership with industry and academia, consistently delivered on AFRL's mission to lead the discovery, development, and integration of affordable warfighting technologies for our air and space forces.

The Air Force, in its quest for war-winning technology for the defense of the nation, expects us to create technology solutions that satisfy gaps in needed warfighting capabilities, rapidly respond to urgent technology needs, and lead the discovery of "game changing" opportunities that result in entirely new capabilities. AFRL demonstrated dramatic achievements in all of these areas during this past year.

These pages reflect some of our most noteworthy successes for 2004, yet they represent only a small sample of the ongoing achievements of AFRL's scientists, engineers, and many other talented professionals. An accompanying CD-ROM provides a link to the information showcased in this book along with other AFRL technology areas.

If you want to know more about a success story, please contact our technology clearinghouse, TECH CONNECT, at (800) 203-6451, and a team member will direct you to the appropriate laboratory expert. You can also visit our Web site at **www.afrl.af.mil**.

Introduction

The Air Force Science and Technology Success Stories herein often represent the combined effort of several scientists and engineers working as a team. The basic and applied research, plus the follow-on technology development described, are essential to the continued success of the Air Force mission.

Success Stories were selected from one or more of the following categories:

Support to the Warfighter

Technology that has potential for or has achieved application on a Department of Defense system in development or operation or that has provided "quick-reaction" response to problems or needs of field organizations.

Emerging Technologies

Major innovative technological advancements that offer significant potential for existing and future Air Force systems.

Technology Transfer

Technology that has transferred from the laboratory to the private sector, to include industry, academia, and state and local governments.

Awards/Recognition

Awards or recognition by the scientific community at large, concerning technology advancements in the areas of technology transition, technology transfer, or technical achievement.

Support to the Warfighter

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Support to the Warfighter

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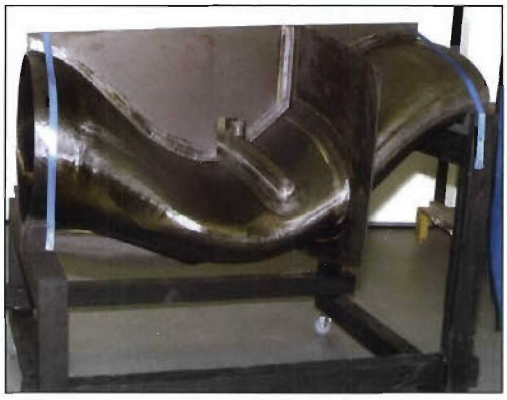
Structurally Integrated Compact Inlet Technology

Payoff

Engineers can now use composite layup techniques with production equipment to build a single-piece diffusing duct using 100% composite material without fasteners. The resulting duct is lighter, stronger, and easier to manufacture than current designs. This technology will be applicable and available to a wide array of unmanned and manned air vehicles, including the Joint Unmanned Combat Air System.

Accomplishment

The AFRL Air Vehicles Directorate's Composites Affordability Initiative and Inlet Aerostructural Integration programs and Lockheed Martin Advanced Development Programs (ADP) successfully demonstrated structurally integrated compact inlet technology (STRICT). The STRICT program uses automatic composite fiber placement and other state-of-the-art manufacturing techniques, producing a highly compact, fully offset, single-piece diffusing duct with integrated flow control devices and sensors. AFRL and Lockheed Martin ADP accurately demonstrated the use of a production-quality tool instead of the one-use-only tool typically used in development.



AFRL scientists overcame significant challenges manufacturing the component. The duct structure required small-turn radii and lateral curvature for compactness, but these attributes could hamper structural rigidity. The duct was manufactured as a single piece for structural integration, simplicity, and elimination of conventional fasteners. To accomplish this, researchers used a large fiber placement machine that could reach into the concave curved surfaces.

Background

The STRICT program demonstrates a flow control technology that satisfies aerodynamic performance requirements using current composites technology for an inlet duct. The use of flow control allows STRICT to develop ducts that are shorter than those previously used, thus allowing smaller unmanned air vehicle designs.

The system produced in this project is sized to fit the X-45A Unmanned Combat Air Vehicle (UCAV) program engine. Three factors influence the size of current UCAV concept designs: mission parameters, payload, and propulsion integration. The STRICT program influences propulsion integration, providing more compact integrated propulsion systems with performance comparable to, or exceeding, that of much larger systems.

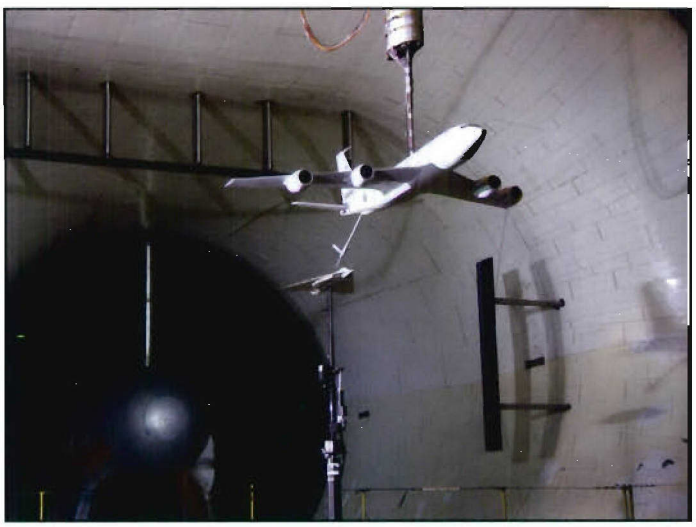
Advanced Simulation Tools Enable UAV System Aerial Refueling

Payoff

AFRL developed test techniques and software to measure aircraft aerodynamic characteristics while in close formation, advancing the state of the art in modeling and simulation. AFRL scientists are using this technology to make future unmanned air vehicle (UAV) systems capable of aerial refueling. UAVs with this ability will stay on station much longer and fly greater distances, increasing mission effectiveness and reducing forward basing requirements.

Accomplishment

The AFRL Air Vehicles Directorate worked with Bihrle Applied Research, Inc., under a Small Business Innovation Research program contract to improve simulations of UAV systems flying in close formation. Scientists developed test techniques, apparatus, and data acquisition software for use during wind tunnel tests to measure close formation aircraft aerodynamic characteristics. Scientists are using data from the wind tunnel tests to develop advanced flight control algorithms for direct implementation into simulation models.



Scientists also created a comprehensive simulation capability that allows users to load multiple independent simulations into a single application. This capability allows a single flight model to be reused during a single simulation session. By loading two or more simulations into the environment, an engineer may apply a global control algorithm to a simulated formation flight scenario.

Until now, development sessions like these have required multiple simulations running on multiple computers or a single complex simulation structure. The new advanced simulation capability will greatly simplify the complex task of modeling multiple vehicles while requiring less development time for engineers.

Background

The development of models for close formation flight historically has been based on computational aerodynamics. While this approach is good for preliminary estimates, it results in oversimplification of the aerodynamic phenomena, which often leads to the development of low-fidelity modeling.

AFRL's new simulation technology is enabling aerial refueling of UAV systems under the Autonomous Aerial Refueling program. Wind tunnel testing was conducted on three tanker/receiver aircraft combinations. Two tests were conducted using a KC-135R tanker, one with a generic UAV and one with the Boeing X-45C. The additional test used a Navy F-18 as the tanker (simulating "buddy" refueling) and a generic UAV as the receiver. All tests were conducted in the Langley full-scale wind tunnel, currently operated by Old Dominion University.

AFRL Software Aids in A-10 Maintenance

Payoff

AFRL developed software that the Ogden Air Logistics Center (OO-ALC) used to design the first A-10 boron patch. This software, as part of the Composite Repair of Aircraft Structures (CRAS) program, provides a design and analysis tool for bonded repairs that decreases maintenance and support costs while increasing aircraft availability.

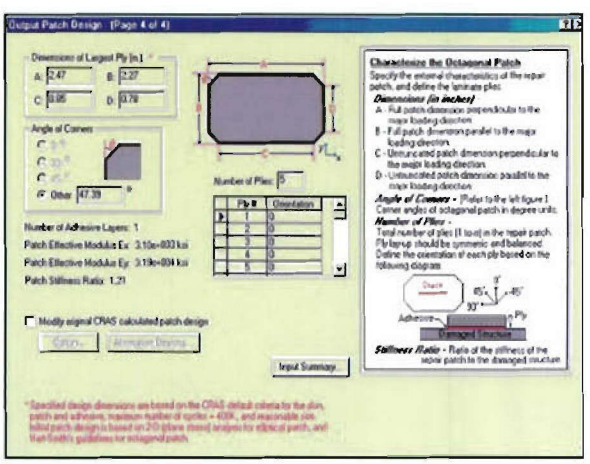
Accomplishment

The AFRL Air Vehicles Directorate coordinated with Boeing to develop CRAS software. CRAS provides validated and demonstrated technology improvements for bonded repair design and analysis of bonded repairs to a damaged metallic structure.

This technology was transitioned to OO-ALC personnel, who used it to design a patch for an A-10 wing segment. Technology challenges addressed by CRAS and applied to patch performance include nonelliptical patch configurations, out-of-plane bending, residual thermal stress, skin thickness effects, elastic-plastic bondline analysis, proximity influence of adjacent patches, and tapering effects.

Background

In the past, cracks in aging aircraft structures were repaired with mechanically fastened repairs to restore static strength and restrict damage growth. These repairs were easily installed, but they had significant drawbacks, including weight addition, parent material removal, and stress riser introduction. Currently, adhesively bonded composite repairs are a desirable alternative.



Bonded repairs are lightweight, thin, and corrosion resistant, and they conform to the original structure. They eliminate stress risers because bonding a composite patch to the structure eliminates the need to drill holes for fasteners. In addition, the composite patch does not interfere with nondestructive inspection of the underlying damaged structure.

CRAS is a Microsoft Windows® application. It creates and analyzes designs for bonded composite repairs to metallic structures with cracks and corrosion grindout areas. It also uses a finite element model generator to analyze repairs for holes, holes with grindouts, dents, and cutouts. The Windows graphical user interface displays the CRAS results, which can be printed.

In the first practical application of the CRAS software, OO-ALC scientists designed a patch used to repair a corrosion grindout on the A-10's upper wing surface. The CRAS software is also being used to fix a crack in the A-10 wing station 90. Use of these patches will decrease fleetwide A-10 depot time, resulting in decreased maintenance costs and increased aircraft availability for the warfighter.

C-130 Durability Patch Demonstration a Success

Payoff

AFRL successfully demonstrated a life-extending structural damping patch for the C-130 (Hercules) aircraft. The patch has the potential to prevent, or significantly delay, the development of high-cycle fatigue cracking, decreasing repair costs and increasing operational readiness. The demonstration's success opens the door to increase the use of damping treatments to mitigate high-cycle fatigue cracking currently occurring in many aircraft.

Accomplishment

The AFRL Air Vehicles Directorate worked with the North Carolina Air National Guard (NCANG) to demonstrate a life-extending structural damping patch on an operational C-130. The patch, created and installed by Damping Technologies, Inc., was made from layers of aluminum and a viscoelastic material. For the demonstration, the patch was attached to a panel behind one of the C-130's engines. Engineers selected the C-130 aircraft panel because of its frequent cracking rate. Previously, the panel required repairs in about half of NCANG's C-130 fleet.

Prior to the demonstration, AFRL engineers collected vibration and temperature data on the designated panel during five flights, using an AFRL-developed data acquisition system called the Damage Dosimeter. After the patch was applied, engineers collected vibration and temperature data for seven additional flights. When engineers compared data from these two sets of flights, they found the patch decreased strain on the panel. This outcome indicated that the patch could increase the panel's life by 4.6 times. AFRL plans to keep the patch on the C-130 for the remainder of its life for continual evaluation.

Background

Fatigue cracking, caused by vibration, is common on most aging aircraft. Energy from sources such as airflow, acoustic loads, or engine vibration can cause vibration in the panel. A damping patch dissipates this vibrational energy, decreasing the panel's peak deflections during each flight.

Typically, panels with fatigue cracking are repaired using a reinforcing panel fastened with rivets. The reinforcement helps the panel survive the load, but the rivets introduce stress risers and transmit the vibration to the surrounding structure, causing fatigue cracking to spread. This phenomenon, called "crack-chasing," requires these surrounding areas to be reinforced, which can create additional problems. The damping patch prevents crack-chasing by dissipating vibrational energy without transmitting it to the surrounding structure.

The AFRL Combined Environment Experimental Validation Facility Is Upgraded

Payoff

The AFRL Combined Environment Experimental Validation Facility is the largest thermal-acoustic validation facility in the world. The facility provides state-of-the-art validation capabilities to all government agencies and to industry and academia through cooperative research and development agreements.

Accomplishment

The AFRL Air Vehicles Directorate recently oversaw the completion of a $19 million military construction project to upgrade a preexisting World War II static test building located at Wright-Patterson Air Force Base, Ohio. The result, the Combined Environment Experimental Validation Facility, is the world's premier aerospace vehicle structure research and development facility. It has various acoustic chambers capable of subjecting specimens up to 4.5 ft by 9 ft in size to temperatures up to 2500°F and sound pressure levels up to 173 dB. Its random fatigue validation capabilities include exertion of 20,000 lbs random force dynamic vibration and/or 25,000 lbs controlled variable force dynamic vibration on specimens.

Researchers are using these capabilities to simulate the different environments encountered by air and space vehicles. Using simulation data, they can develop accurate prediction methods for structural response and acoustic fatigue life of advanced structures used on air and space vehicles. In addition, they are researching vibration technologies that may enable lower-cost and higher-performance flight vehicles. Some examples of this research include hypersonic flight vehicle structures, thermal protection system advancements for current space platforms and future space operation vehicles, field repair of fatigue cracking, and buffet suppression.

Background

The building housing the Combined Environment Experimental Validation Facility was built in 1944 as a static test facility for the B-36 Peacemaker, an intercontinental bomber aircraft. The B-36 had a 230 ft wingspan and was 162 ft long. The building was large enough to allow the B-36 to be raised vertically with its nose pointing straight up.

The facility's mission is to further aerospace structure technologies through research and development. Through modeling techniques, analytical prediction, and exposure of structures to the stresses of noise, vibration, and heat, researchers study the conditions experienced by air and space vehicles during flight. Scientists use the results of this research to solve various aircraft dynamics problems and ultimately increase aircraft readiness levels.

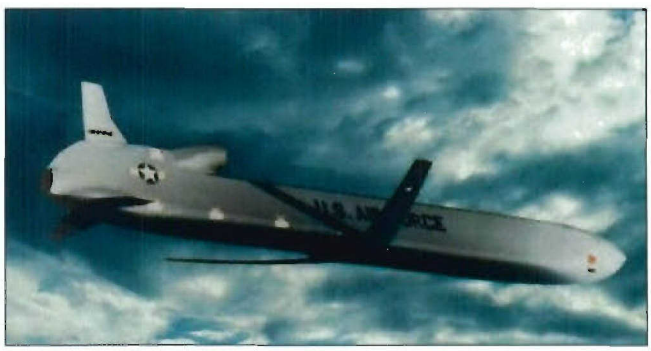
AFRL Contributes to AGM-86D Advancements

Payoff

AFRL scientists provided technical expertise and improved simulation modeling of the AGM-86D deep-penetrator cruise missile for the Oklahoma City Air Logistics Center (OC-ALC) at Tinker Air Force Base. This support resulted in increased missile accuracy.

Accomplishment

AFRL scientists spent 9 months assisting the OC-ALC effort to increase accuracy of the air-launched, deep-penetrating AGM-86D cruise missile. During this time, the AFRL Air Vehicles Directorate, acting as OC-ALC's technical advisor, provided an independent verification and evaluation of contractor weapon simulation results. AFRL monitored and evaluated the program's technical effectiveness and progress, identified technical issues, provided corrective advice, modeled the dynamic effects of sloshing fuel on the missile's mass properties, and performed state-of-the-art computational fluid dynamics (CFD) analysis to provide more aerodynamic data in needed areas.



AFRL scientists used the modeling and CFD results to make improvements to the AGM-86D weapon system simulation, increasing simulation accuracy. The simulation then created mission screen data or charts used to target the missile based on atmospheric and target conditions and preferred missile trajectory. Engineers also verified AGM-86D accuracy goals during their independent survey of the missile's targeting accuracy.

Background

The AGM-86D air-launched cruise missile (ALCM) is a conventionally armed, long-range, standoff missile produced by modifying surplus nuclear-armed AGM-86B ALCMs. The problem arising from this conversion was the conventional missile's higher accuracy requirements. In response to this requirement, OC-ALC initiated an accuracy enhancement program with Boeing, the AGM-86B designer. OC-ALC also sought AFRL's expertise in missile guidance, navigation, flight control, aerodynamics, and computer simulation.

The AGM-86D has an advanced penetrating warhead, which allows the warfighter to precisely attack the enemy's most valuable facilities from hundreds of miles away. The penetrator warhead waits to detonate until after the missile has penetrated a hardened, buried target such as an underground bunker. Using the AGM-86D with air-refueling and long-range bombers enables the Air Force to launch highly accurate conventional attacks against nearly every target in the world from within the continental US.

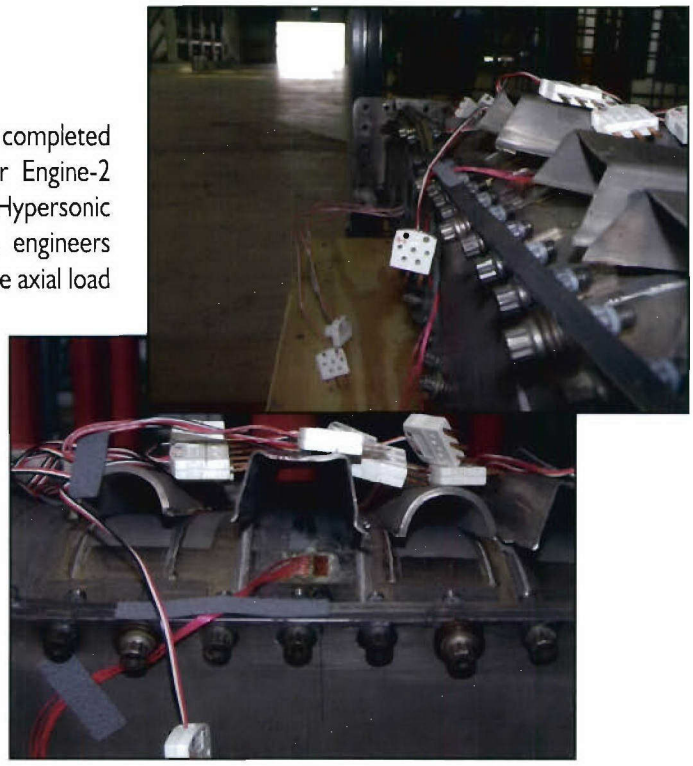
AFRL Provides Experimental Validation on Scramjet Combustor

Payoff

AFRL provided critical experimental validation testing making hypersonic vehicle technology a reality. Hypersonic engines may one day power missiles, launch vehicles and long-range aircraft.

Accomplishment

AFRL's Aerospace Structures Research Facility successfully completed static pressure validations on the Ground Demonstrator Engine-2 (GDE-2) scramjet combustor box to support the Air Force Hypersonic Technology program. During the experiments, AFRL engineers designed a test fixture that used pneumatic jacks to eliminate axial load on the test article while increasing the internal pressures on the GDE-2 combustor box until it experienced structural failure.



The experimental validation was a success. The GDE-2 experienced structural failure at 200 lbs per square inch of pressure, which is 2.3 times more pressure than it is required to withstand. The successful team effort saved the Air Force money and brought hypersonic technology one step closer to reality.

Background

The AFRL's Aerospace Structures Research Facility is the largest combined environment experimental facility in the world. It provides state-of-the-art validation capabilities to all government agencies and to industry and academia through cooperative research and development agreements. In addition to the static pressure validation capabilities used for these experiments, the facility can simultaneously expose structures to mechanical loads, noise, vibration, and heat to simulate conditions experienced by air and space vehicles during flight. Scientists use this research to solve various aircraft dynamics problems and ultimately increase aircraft readiness levels.

AFRL Demonstrates New Simulation Environment

Payoff

The AFRL Air Vehicles Directorate successfully completed the first demonstration of a new simulation environment, the Space Access Vehicle Mission and Operations Simulation (SAVMOS) facility, to enable engineers to assess reusable military launch systems (RMLS). The facility capabilities will enable scientists to accurately evaluate new technologies and aerospace vehicles prior to putting valuable resources into construction.

Accomplishment

AFRL developed the simulation environment by integrating existing simulation capabilities into a unique simulation environment for military space vehicle operations. During this demonstration, a space maneuver vehicle was launched to low earth orbit, where it deployed a payload. The space maneuver vehicle then completed an on-orbit mission replan to perform a battle damage assessment of a target area before reentering the atmosphere to land at the launch site. In addition to simulating these types of missions, the directorate will be able to assess technologies such as rapid flight planning, integrated vehicle health management, and rapid vehicle turnaround by using the SAVMOS facility.

Background

The SAVMOS facility supports the development of reliable and cost-effective RMLS. One day, RMLS may provide launch-on-demand space access with the ability to turn around quickly between missions. For example, an RMLS analagous to the space shuttle could turn around in hours instead of the months currently required. Developing a reliable flight simulation capability is essential to determine if new technology is viable prior to actually building it. In addition, simulation enables potential end-users to become involved with the initial design phase to help identify system weaknesses early in the design process.

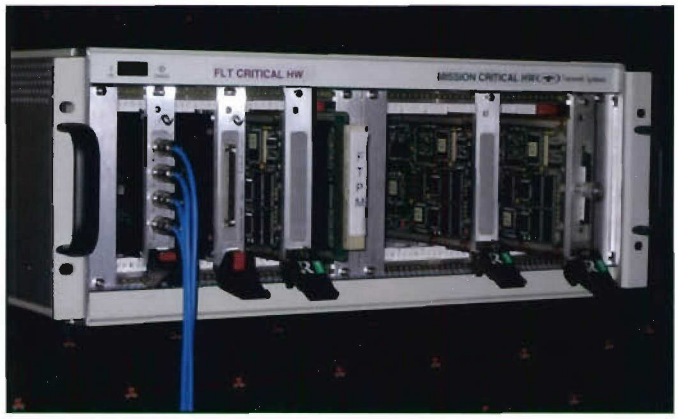
Control of Multimission UAV Systems

Payoff

Control of Multimission Unmanned Air Vehicle Systems (CMUS) vehicle management system computer hardware is a combination flight control and mission control computer that will save space and weight. This system will enable engineers to design flight control systems with the reliability of manned aircraft in a size and weight appropriate for smaller, unmanned air vehicle (UAV) systems.

Accomplishment

AFRL scientists successfully created and demonstrated in the laboratory environment a new air vehicle hardware system that joins a flight control computer with a mission control computer. This system, part of the CMUS program, brings the computers together in one location. It allows them to share information effectively and still retain their separate functions. In addition, CMUS has a fail-safe feature that ensures the flight control computer has priority if a conflict arises between the two computers. By colocating and linking the two computers, CMUS eliminates the need for network connection hardware used in conventional air vehicle designs. As a result, the system saves weight and space.



AFRL developed CMUS in support of the Joint Unmanned Combat Air Systems (J-UCAS) program. However, the technology potentially may benefit all future air vehicles.

Background

The J-UCAS program is a joint Defense Advanced Research Projects Agency/Air Force/Navy effort to develop UAVs to carry out missions like surveillance, precision strike, and enemy air defense suppression.

AFRL Completes Electromagnetic Characterization on Army Vehicles

Payoff

AFRL scientists and engineers conducted qualification tests for the US Army. AFRL personnel planned, set up, and performed electromagnetic tests on two armored vehicles to qualify them for a combat environment. The Army's two armored vehicle models contain electronics that are now qualified for high-level electromagnetic fields that might be encountered in the current world crisis.

Accomplishment

The AFRL Directed Energy Directorate's Wideband Technology Group responded to a call from the Army to supply equipment and system-level test expertise to qualify its Stryker personnel carrier and an Abrams tank to a specified high-level electromagnetic field in a realistic environment. Using unique laboratory-developed equipment, the group successfully performed a complete characterization on the two vehicles at the High-Energy Research and Technology Facility at Kirtland Air Force Base, New Mexico. The group tested multiple units to measure test-to-test variations.

Background

In today's warfighting environment, it is necessary to have vehicles that are qualified to operate in high-power electromagnetic fields. This requires appropriate equipment and sensors, as well as personnel with the knowledge and skill to perform system-level tests on large vehicles in a realistic outdoor environment.

Watch-Standing Study for Submariners Prepares Way for At-Sea Trials

Payoff

The US Navy recently enlisted AFRL's scientific expertise to evaluate the effectiveness of the 18-hour maritime watch-standing schedule adopted in the 1960s. Commanders of nuclear and fast-attack submarine crews recognized performance challenges and requested an evaluation by the Naval Submarine Medical Research Laboratory (NSMRL) and AFRL's experts on shift work. An initial joint-service study at Brooks City-Base, Texas, demonstrated that a human-centered, 24-hour schedule could improve submariner circadian physiology and performance.

Accomplishment

AFRL scientists created an alternative 24-hour watch-standing schedule that rotates crews on a 72-hour shift schedule. The schedule provides crews with 6-hour watches and 12- to 24-hour off-duty shifts. The initial study suggests that the alternative schedule increased sleep duration and improved submariner performance during the 18-hour and traditional watch-standing schedules.

AFRL's Human Effectiveness Directorate scientists and NSMRL conducted the initial study at the Chronobiology and Sleep Laboratory at Brooks City-Base. The study aligned the submarine watch-standing cycle with the human body's 24-hour wake/sleep cycle to improve performance. Researchers tested the submarine 18-hour schedule against a traditional maritime 24-hour schedule and the alternative 24-hour schedule.

Dr. James C. Miller, of the AFRL Human Effectiveness Directorate, designed the alternative watch-standing schedule. Scientists from the collaboration expect the alternative schedule's at-sea trial to expand upon and confirm the lab-based findings, potentially ushering in a change in the Navy's 30-year watch-standing policy. The schedule can have significant benefits to other settings as well, especially the command, control, communications, computer, intelligence, surveillance, and reconnaissance teams on the ground who are living and working 24 hours a day, 7 days a week (24/7) within one fixed site.

Background

Increased technology mandates the 24/7 operations needed for today's fighting forces. Sophisticated sensors and equipment generate increased information processing demands for the submariner. These demands require the submariner to perform optimally throughout each watch. Today's combination of sustained operations and optimal performance creates stresses on America's volunteer forces, impairing their performance. This stress adversely affects the quality of life and retention of experienced and highly trained personnel.

Total Atmospheric Liquefaction for Oxygen and Nitrogen System Design Completed

Payoff

Air Force (AF) heavy airlift aircraft require oxygen for life support systems and nitrogen for inerting the aircraft's fuel tanks. The nitrogen atmosphere above the fuel prevents an explosion if small arms fire ruptures the tanks. Scientists designed total atmospheric liquefaction for oxygen and nitrogen (TALON) to simultaneously produce liquid oxygen and nitrogen aboard an aircraft. The single system has triple benefits: reducing deployment footprints, reducing liquid oxygen supply infrastructure costs, and resolving current deficiencies with fuel tank inerting systems.

Accomplishment

The AFRL Human Effectiveness Directorate at Brooks City-Base, Texas, collaborated with Creare, Inc., of Hanover, New Hampshire, and Boeing, to develop a detailed design for a flightworthy, palletized TALON demonstration system. The palletized design will reduce development program costs and minimize aircraft modifications required to install the demonstration system on the C-17.

The effort showed how the TALON system could be fully integrated into the C-17 aircraft. AFRL based the program upon the results of its prior funded work aimed at liquifying and storing oxygen for field hospitals and aeromedical evacuation use. Previous Small Business Innovation Research Phase I and II contracts to develop miniaturized distillation and cryogenic refrigeration technologies also contributed significantly to the success of the TALON program.

TALON replenishes the onboard liquid oxygen and nitrogen supplies, reduces the US Air Force deployment footprint, and supports the AF critical future capability of agile combat support. TALON reduces the estimated 20-year, $1.5 billion dependence on the liquid oxygen production and servicing infrastructure. An additional benefit would be a potentially highly reliable and low-maintenance onboard fuel tank inerting system.

Background

Congressional aid and AF science and technology funding supported AFRL's development to achieve a viable onboard gas generation technology for the C-17 and other airlift aircraft. System design, aircraft integration, and key component demonstrations were several key feasibility issues studied to lower the technical risk during the effort.

The TALON system is intended primarily to meet the AF's need for oxygen and fuel tank inerting systems. However, following the midair explosion of TWA flight 800, there was increased interest in fuel tank inerting systems for commercial passenger aircraft. TALON technology could be used on mid- to large-sized passenger aircraft as well as to satisfy the requirement for small portable oxygen and nitrogen generating plants.

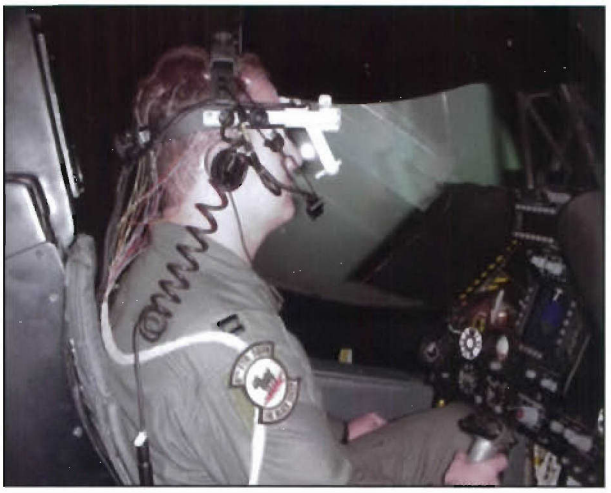
F-117 Study Expands Fighter Pilot Fatigue Knowledge

Payoff

AFRL scientists conducted a study that may help military aviators combat the performance-degrading effects of fatigue during long-duration missions. Warfighters will benefit from this study designed to improve mission performance among aircrews in all types of aircraft, whether they are transport planes, bombers, fighters, or helicopters.

Accomplishment

The AFRL Human Effectiveness Directorate's Warfighter Fatigue Countermeasures Team conducted the study to assess several fatigue factors using 10 F-117 pilots at Holloman Air Force Base, New Mexico. The research revealed that pilots who flew simulators for 37-hour missions experienced marked fatigue-related problems. The study showed their basic flight skills degraded to 40% below normal due to the imposed sleep loss.



This is an important finding, because researchers have long assumed that basic flight capabilities are extremely resistant to operational stressors such as fatigue. The study also indicated the most serious fatigue-related decrements occurred not in the predawn hours, as many had expected, but were instead observable much later in the day, even as late as 2 to 3 pm, after 32 hours without sleep. Furthermore, the sleep-deprived pilots were often unable to reliably self-assess their alertness and readiness to perform.

During the study, no one "crashed" the simulator, but it became clear that untreated fatigue could seriously impair operational readiness at unexpected times without the pilot's knowledge. The results provide a baseline for improving aircrew sustained operations risk analysis and validating fatigue countermeasures. These counterfatigue strategies will include sleep schedule changes, behavioral remedies, and pharmaceutical aids designed to enhance performance while preventing mishaps.

Background

According to US Air Force Safety Center data, nearly 8% of reported Class A Air Force mishaps during the past 30 years have been partially caused by aircrew fatigue. Army aviation did not fare much better, with 4% of Class A-C aviation mishaps between 1990 and 1999 also fatigue related. Today's ever-escalating operational tempo requires implementation of effective, scientifically validated fatigue countermeasures to keep aviators alert without sacrificing safety.

New Night Vision Test Method Saves Money

Payoff

Ordinary aircraft maintenance teams are now able to perform night vision imaging system (NVIS) lighting evaluations, eliminating the need for specialized contractor teams equipped with expensive laboratory-grade equipment. This advance will save the Air Force (AF) and civilian aviation tens of thousands of dollars per aircraft test.

Accomplishment

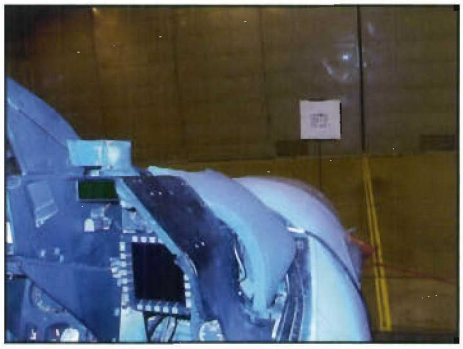
The AFRL Human Effectiveness Directorate developed a test of cockpit lighting NVIS compatibility that requires only inexpensive, readily available equipment and that can be accomplished by any technically competent aircraft maintenance team. This method was then transitioned to the Federal Aviation Administration (FAA).

The new method is based on the assessment of aviator visual performance through night vision goggles (NVG) with the candidate NVIS lighting. The new equipment consists of slightly modified off-the-shelf items, available at large national chain discount stores (e.g., Wal-Mart) and photographic supply shops or available free from certain Web sites.

The documentation transitioned to the FAA includes instructions on how to perform the lighting evaluation, a list of recommended equipment and potential vendors, modification instructions for the off-the-shelf items, and the Web address for the preferred visual acuity chart. The FAA and the AF anticipate saving tens of thousands of dollars per aircraft.

Background

AFRL has been developing NVG technology, pioneering NVIS-compatible lighting, and accomplishing NVIS cockpit lighting modifications and evaluations for more than 20 years. The FAA asked AFRL for assistance in developing NVIS lighting test procedures for civil aviation. The FAA was assigned responsibility for certifying NVIS cockpit lighting but lacked an efficient method to accomplish this new task.

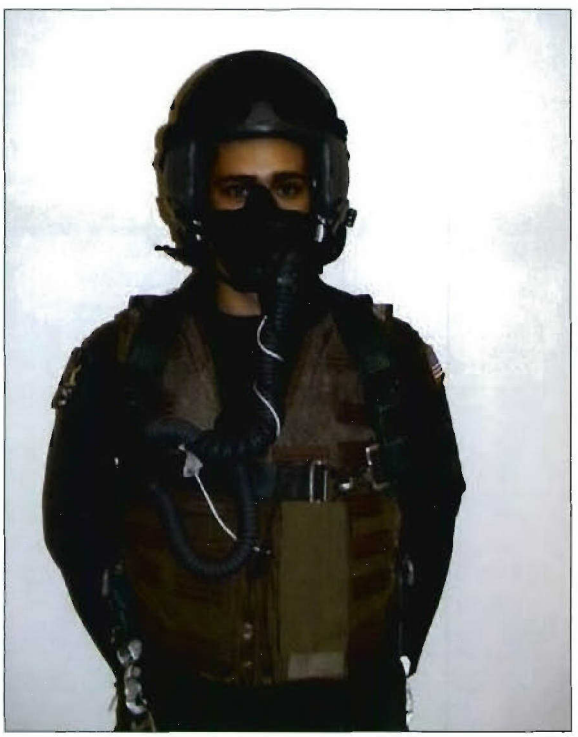


Conventional cockpit lighting evaluations are extremely expensive and slow because they employ specialized teams of contractor personnel who must travel to the modified cockpit and then assess it using expensive laboratory-grade equipment. The cost of equipment and training makes this conventional self-testing approach prohibitive.

Head-Mounted Photometer System for Airborne Luminance Measurement

Payoff

AFRL developed a head-mounted photometer (HMP) system that a pilot wears during flight to record the pilot's luminance exposure during an extended period. The data is then used to characterize and mathematically model the effects of different visor and aircraft transparency transmissivities on the warfighter's visual performance.



Accomplishment

AFRL Human Effectiveness Directorate engineers designed, built, and tested the new system for airborne applications. The HMP is a rugged, compact, battery-powered system that a pilot wears during flight.

The system is composed of an optical light sensor that is attached to the side of the pilot's helmet and measures the lighting conditions in the general direction of the pilot's gaze. It is electronically connected to a data recorder worn in the pocket of the survival vest. The HMP system enables the collection of large amounts of luminance data during extended periods and under a wide variety of flight conditions.

Background

In order to more accurately design optical coatings, helmet visors, and aircraft transparencies, it is necessary to determine the ambient luminance conditions to which warfighters are exposed during flight. The HMP system was developed to collect this data.

Once the luminance ranges are sufficiently characterized, the effects of different transparent elements can be mathematically modeled. These results may affect the design of many visors, aircraft transparencies (including their coatings), and laser eye protection. For example, the current transmissivity specifications may be modified to enhance air-to-air target acquisition performance. The HMP is a viable tool for use in addressing human factors issues associated with the development of transparency technologies.

Evaluation Selects an ANR Headset for AWACS

Payoff

AFRL researchers conducted critical evaluations to select the best commercial off-the-shelf (COTS) active noise reduction (ANR) headset for use in the Airborne Early Warning and Control System (AWACS) E-3 aircraft. ANR headsets will provide a more comfortable and intelligible communications environment, and more importantly, will provide protection against the damaging effects of the constant noise environment on the operator's hearing.

Accomplishment

The AFRL Human Effectiveness Directorate's evaluation techniques and tools were able to identify the best ANR headset for the AWACS operators from nine COTS contenders. The winning headset was selected for acquisition and will become standard equipment for AWACS crews.

The results of the evaluation answered critical questions regarding headset vendor selection. Colonel Lester R. Calahan, head of Air Combat Command Requirements for Command and Control, Intelligence, Surveillance, and Reconnaissance, sent a letter of appreciation for AFRL's evaluation efforts. In the letter, he noted that the information provided by AFRL and the operational utility of AWACS in all combatant theaters using this innovative technology will pay big dividends in the future by decreasing long-term hearing loss and impacts of fatigue for more than 1,300 assigned flyers.

Background

The AWACS mission often requires operators to endure long exposures to the noisy aircraft environment. The noise can degrade communications and hearing ability during the course of an operator's career.

The evaluation incorporated objective tests of headset performance and parameters along with a subjective evaluation of the various headsets' suitability for the AWACS. The scores on these parameters were combined according to the decision weights collected from experts. The nine contending headsets were evaluated to select the two best contenders. The two top contenders were directly compared to determine the winner.

AFRL's CHEMRAT Software Delivered 2 Years Ahead of Schedule

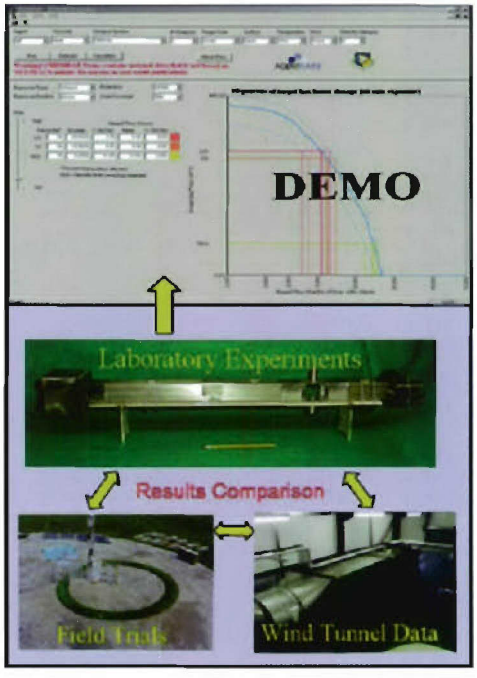
Payoff

AFRL developed and transitioned a chemical hazard estimation method and risk assessment tool (CHEMRAT) to the Air Force (AF). CHEMRAT enhances the ability of chemical, biological, radiological, and nuclear operators and commanders to make critical risk management decisions, providing integrated risk-based solutions to meet the operational needs of both civil engineering and medical personnel advising the base commander.

Accomplishment

The AFRL Human Effectiveness Directorate successfully fulfilled the AF's urgent request for the tool in less than 90 days. The CHEMRAT team secured funding and approval from the Office of the Secretary of Defense to accelerate the program.

They expanded the CHEMRAT capabilities by incorporating new medical requirements and new threat parameters provided by Headquarters Air Force staff and executed over 90,000 computer runs to populate the CHEMRAT database. In addition, they delivered test and evaluation copies of CHEMRAT, 2 years ahead of schedule, to the Air Force Civil Engineer Support Agency, Air Force Surgeon General, Marines, Army, and North Atlantic Treaty Organization. CHEMRAT was transitioned to the Space and Naval Warfare Systems Command and the Joint Service Chemical and Biological Defense program's acquisition program manager for the Joint Operational Effects Federation program.



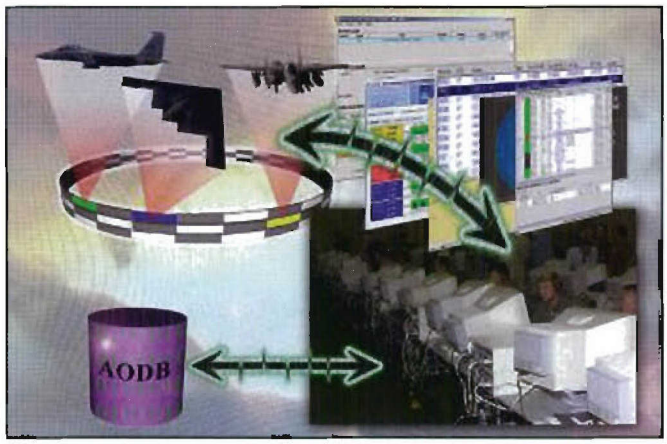
Background

CHEMRAT was originally developed as an advanced concept demonstration to enhance future chemical agent prediction capabilities for the warfighter. Due to potential future operations, the AF requested immediate acceleration of the CHEMRAT program to support post attack risk assessment of chemical warfare agents. There is no other tool like CHEMRAT available in the AF that allows for the efficient assessment of risk for reduced mission-oriented protective posture operations in a chemical warfare environment.

Quick, Accurate DLARS Assessment Propels Spiral 2 Goal Achievement

Payoff

Today's warfighters need the best tools at the right place at the right time to fight ever-changing enemies. Lessons learned from each Joint Expeditionary Force Experiment (JEFX) phase or spiral help meet warfighters' needs in near real time. The urgency and necessary fast pace of JEFX allows participants time to concentrate and reflect on only high priority emergent technologies. Collaborations with experts across AFRL can assist JEFX participants to address important issues that affect technologies and processes for command and control systems, such as interface usability.



Accomplishment

Dr. Scott Galster, of the AFRL Human Effectiveness Directorate, quickly and accurately assessed the data link automated reporting system (DLARS) interface at the JEFX Spiral 2 Experiment at Nellis Air Force Base, Nevada, for the Command and Control (C2) Battlelab. DLARS provides data link information on aircraft fuel levels, as well as target and weapon status.

The DLARS team immediately implemented the majority of Dr. Galster's suggestions for improved human-computer interaction. These suggestions included methodologies that allow operators to manipulate data in a more efficient manner. An expert in data displays, Dr. Galster met one-on-one with each DLARS engineer and produced a timely report to guide the work for DLARS displays over the next few months. The DLARS team achieved all its Spiral 2 goals with Dr. Galster's participation.

Background

Experts in human interaction with automated systems, AFRL personnel partnered with the C2 Battlelab on the DLARS project to improve data management and manipulation. Dr. Galster used a heuristic approach to evaluate the DLARS interface and, based on his findings, made suggestions for improvement. In most instances, DLARS personnel directly involved in the programming interface implemented his changes the next day.

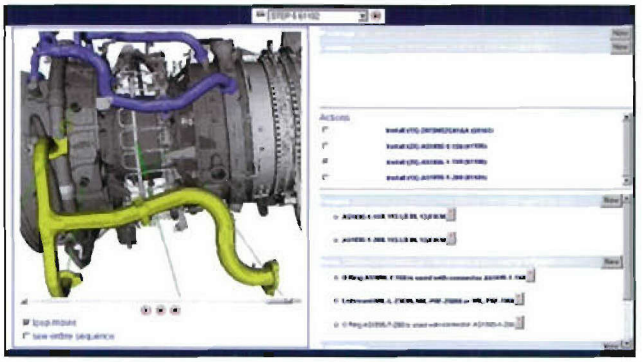
AFRL-Sponsored Technology Reduces Joint Strike Fighter and Commercial Aircraft Maintenance Manual Development Time

Payoff

Air Force systems are often plagued by incomplete and inaccurate maintenance manuals. Automating critical aspects of technical manual development will provide more timely and accurate maintenance manuals at a fraction of the time and cost of producing conventional manuals.

Accomplishment

The Service Manual Generation (SMG) dual-use program, sponsored by AFRL's Human Effectiveness Directorate, successfully demonstrated a dramatic reduction in procedure/method planning and documentation process time. General Electric Aircraft Engines (GEAE) demonstrated the SMG technology on the Joint Strike Fighter engine design and on its new, GP7200 commercial engine design. These demonstrations consistently show that SMG provides a 2x - 4x speed increase over current maintenance planning efforts. Further, SMG automatically generates state-of-the-art, fully hyperlinked assembly/disassembly animations that could revolutionize procedures documentation. GEAE plans to transition SMG into a commercial product.



Background

The Department of Defense spends millions of dollars annually on maintenance instructions for its weapon systems. SMG is automating critical aspects of technical manual development to provide more timely and accurate maintenance manuals at a fraction of the time and cost associated with preparing conventional manuals. Additional benefits include the ability to evaluate maintenance during early stages of design and propose more affordable design changes to ease the maintenance burden.

AFRL Demonstrates Protected Tactical WLAN SATCOM Gateway

Payoff

AFRL demonstrated a mobile wireless local area network (WLAN) satellite communications (SATCOM) gateway during the Phoenix Warrior Exercise in Fort Drum, New York. The gateway features special technology to enhance information assurance (IA) and provides a protected wireless connectivity footprint at deployed locations.

The mobile Ka-band SATCOM terminal provides automatic acquisition and tracking over varying terrain, acceleration, and speed via a gimbaled 24 in. dish under a radome on the back of a highly mobile multipurpose wheeled vehicle (HMMWV). The gateway interface supports standard networking equipment, and rates up to and including T1 (digital transmission line, 1.544 MB per second, 24 voice channels) can be achieved.

Accomplishment

The WLAN portion of the system comprises a commercial off-the-shelf wireless access point (AP) augmented with a unique five-sector adaptable antenna and the AFRL Information Directorate's wireless intrusion detection sensor (WIDS). Additional security enhancements in the system include a firewall, robust mutual authentication, strong encryption, and virtual private network security over the wireless link.

The unique five-sector antenna enables the system to isolate anomalies indicative of a wireless attacker identified by WIDS while striving to maintain network connectivity for legitimate users. The adaptable antenna can also be used to physically limit coverage to only those areas where it is needed.

Background

The gateway system comprises two essential elements that together provide untethered multiuser access within the system footprint and long-haul reach back to distant networks. First, the WLAN AP, combined with specialized antennas and IA mechanisms, provides high-speed local coverage to clients near the gateway vehicle. Second, a vehicle-mounted mobile Ka-band SATCOM terminal provides a wideband, full-duplex data pipe back to a distant ground station having connectivity to national infrastructure.

Both of these services are usable by clients within a vehicle group or convoy while on the move, at intermittent stopping points along the mission route, or in a stationary encampment. The individual subsystems are integrated and housed on a standard HMMWV that provides a stand-alone, drive-away capability.

Embedded System Modernization Technology Reduces Sustainment Costs for F-117A

Payoff

Pilots from the F-117 Combined Test Force participated in the successful completion of six flight demonstrations testing the F-117A's mission software while using the reconfigurable processor for legacy application code execution (RePLACE) computer emulation technology. TRW, Inc., of Dayton, Ohio, developed the technology under the Reconfigurable Aerospace Computer Emulation (RACE) project. This new system was tested and flown for the first time as an avenue to reduce sustainment costs for the F-117A.

Accomplishment

AFRL developed the embedded information system reengineering (EISR) capability. The AFRL Information Directorate conducted the tests at the Edwards Air Force Base, California, flight test range. The test included a portion of the F-117 operational flight program (OFP) software that was converted from JOVIAL to C programming language using AFRL's EISR capability. The flight demonstrations collected flight test data to determine if the current implementation of emulation technology merits further development.

The flight demonstrations included a navigation checkout, weapons checkout with bomb dummy unit-33, navigation performance checkout, time-over-target/full-scale weapons (FSW) simulation, and FSW delivery with guided bomb unit-12. The resulting OFP function, along with the RACE/RePLACE emulator, ran successfully on the commercial processor. The demonstration marked the first time that reengineered software converted from EISR was flown, and it successfully illustrated that RePLACE legacy and native functions could execute and communicate on the same processor.

Background

The Computer Resources Support Improvement Program (CRSIP) sponsored the RACE project, seeking to address problems associated with legacy/obsolete embedded information systems by using and evaluating emulation technology hosted on the latest commercial processors. The RACE project is working with other customers, including the F-16 Systems Program Office (SPO), the B-2 SPO, and the Special Operations Forces SPO. CRSIP also sponsored the EISR project, created to develop the automation-assisted JOVIAL-to-C reengineering capability that permits simultaneous modernization of both the structure and source language of legacy-embedded system applications. In addition to the F-117 SPO, the EISR project has been working with the F-16 SPO. AFRL provides technical expertise and program management in the development and demonstration of embedded information system technologies to address sustainment issues associated with fielded legacy systems.

The Interactive DataWall—A Command and Control Display System Success

Payoff

Today's battlefield is characterized by the large amounts of information available to decision makers. The conventional approach to utilize complex and expensive signal-switching hardware to display the information hinders the decision-making process. Decision makers require direct access and tighter control of information so they can better manage the environment. AFRL listened to the battlefield commanders and developed a portable, interactive high-resolution datawall.

Accomplishment

The AFRL Information Directorate developed and delivered the Interactive DataWall. The Interactive DataWall is an enhanced computer display that covers a 12 x 3 1/4 ft or 9 x 2 1/4 ft high-resolution screen that the user can manipulate using speech recognition and wireless pointing devices for unencumbered interaction. The Interactive DataWall has been put into use at several locations around the globe—including Osan Air Base, Korea, to support RestOps, for which it facilitates information flow from the field to the Wing Operations Center during the postattack recovery phase.

The Interactive DataWall assists responders in developing an accurate hazard and damage picture, allowing management of recovery efforts. Information is captured electronically and used to generate a common operating picture. The Interactive DataWall was deployed to the US Army's 10th Mountain Division Light Infantry units at Fort Drum, New York, for rapid setup purposes. They used the Interactive DataWall to present updated briefings from various groups within the division, as well as to display live feed from intelligence, surveillance, and reconnaissance assets.

Another Interactive DataWall application is the global concept of operations synchronization. The objective is to improve information sharing and interoperability between Combat Air Forces' and Mobility Air Forces' mission planning and execution for improved velocity, efficiency, safety, and mission success.

Background

The Interactive DataWall evolved from a built-in unit driven by high-end graphics workstations to a portable unit, driven by economical personal computer platforms, that collapses for rapid deployment. The enhanced computer display tiles a computer's multiple video outputs into a seamless, contiguous workspace. The wireless human computer interaction utilizes independent speech recognition via wireless headsets. A camera-tracked laser pointer provides conventional mouse functionality. Examples of data display elements include detailed terrain, land route maps, real-time audio/video communications, airborne surveillance and intelligence information, and archived geographic database information.

NEST Technology Successfully Demonstrated

Payoff

"You can run, but you can't hide." While some liberty was taken with the famous quote from boxing great Joe Louis, its basic premise remains, especially in terms of today's enemy on the battlefields of the world. The Defense Advanced Research Projects Agency (DARPA) and AFRL developed and demonstrated a network embedded systems technology (NEST) that is capable of pinpointing the location of an enemy shooter within 1 meter in an urban environment.

Accomplishment

DARPA's Information Exploitation Office, with support from the AFRL Information Directorate, conducted the NEST demonstration at the McKenna Military Operations in Urban Terrain facility, Fort Benning, Georgia. The field experiment consisted of an integrated demonstration of two separate NEST applications: military operations coordinate grid and shooter localization using a sensor network.

A Massachusetts Institute of Technology team developed the coordinate grid technology, a team from Vanderbilt University developed the shooter localization technology, and military consultants for the NEST program developed the operational scenario for the demonstration. The military operations coordinate grid field demonstration provided real-time tracking of blue, red, and neutral forces within the grid. Active tags were provided to the participants, whose location within the grid appeared on both a handheld personal computer and a laptop computer.

The shooter localization, using a sensor network demonstration, employed an ad hoc wireless network of inexpensive acoustic sensors to accurately locate enemy shooters. The wireless nodes were the basic NEST nodes fitted with a custom sensor board that contained a microphone and some additional processing capability in the form of a field programmable gate array. A number of live fire and blank shots were taken from different areas within the McKenna facility and accurately located by the system. By tracking the shock wave created by the bullet as it moved through the air, the system provided a visual vector in the direction of the bullet.

The Vanderbilt technical approach behind this system was to detect the arrival time of the acoustic shock and muzzle blast when shots were fired within range of the nodes. The demonstration was accurate to within 1 meter in 80% of the shots fired and had a latency of less than a half second.

Background

The NEST program's goal is "fine-grain" fusion of physical and information processes. The quantitative target is to build dependable, real-time, distributed, embedded applications comprising 100 to 100,000 simple computing nodes. The nodes will include physical and information system components coupled by sensors and actuators. NEST nodes will be small and rugged enough to be seeded in operational environments via multiple emplacement modes such as aerial drops, robotic emplacement, and manual distribution. The long-term vision is an intelligent, Web-centric distribution, and fusion of sensor information that will greatly enhance the situational awareness of warfighters.

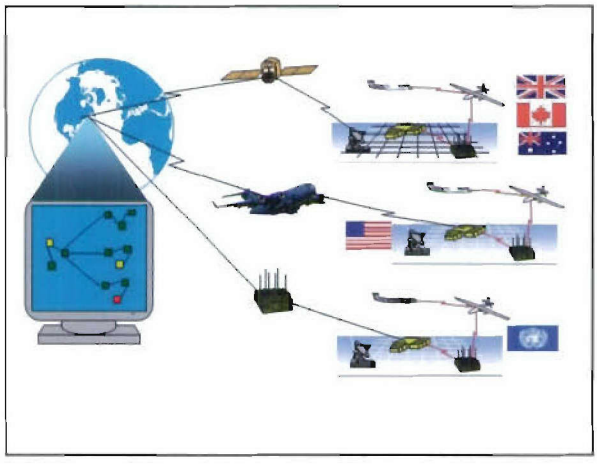
MDNM Advanced Technology Demonstration Transitioned to the ISSE Program Management Office

Payoff

AFRL successfully transitioned the Multidomain Network Management (MDNM) Advanced Technology Demonstration to the Information System Security Environment (ISSE) Program Management Office. This accomplishment will provide cross-domain network management capability to the warfighting community through the ISSE guard platform.

Accomplishment

Representatives from the AFRL Information Directorate and Dolphin Technology, Inc., Rome, New York, demonstrated the security-enhanced (SE)-MDNM project capabilities to Pacific Command representatives at Camp Smith, Hawaii. The capability demonstration was part of the Joint Warrior Interoperability Demonstration.



SE-MDNM combines the security-tested and accredited ISSE guard with the network management capability provided by the MDNM program. SE-MDNM provides the enabling capability of cross-domain network management, allowing a commercial network management system to generate a common network operational picture of multiple networks operating at different security domains.

The Defense Advanced Research Projects Agency provided funding to accomplish the operational evaluation. The Warfighting Rapid Acquisition program provided the transition dollars necessary to incorporate this critical capability into the ISSE guard baseline spiral development.

Background

MDNM provides the warfighter with the enhanced capability of having an enterprise-level common operational picture that shows all networking assets and the ability to monitor and manage multiple security and coalition domains from one centralized network management station. The approach for achieving this objective is through the development of a network management architecture that uses a commercial network management system to monitor the status and control the health of multiple network domains, each of which is associated with a different security caveat. The management is achieved by using a boundary device (or controlled interface) to pass network management information between each network domain and the centralized master station. The focus of the ATD is to protect the information transfers by securely controlling the network management protocol in a boundary device.

Successful Integration of Battlefield Air Operations Kit Software

Payoff

The US military has its eyes on enemy troop movement via the successful integration of Battlefield Air Operations (BAO) kit software. AFRL's Information and Sensors Directorates developed the software in close coordination with several other Department of Defense agencies to identify and locate targets, transmit the data to the Air Operations Center for target approval, and relay approval to the strike aircraft.

Accomplishment

The BAO kit targeting software was integrated with the navigation software for the man-packable unmanned air vehicle (UAV), allowing close air support (CAS) users to generate and quickly send "eyes-on" mensurable target information along the BAO targeting chain. Real-time targeting information available to the combat controller can now be immediately sent over existing communication networks as authorized targets to the CAS pilots.

The software includes the BareBack, which integrates the range finder, Global Positioning System, and radio with UAV navigation software to send messages (with acknowledgement) over the doctrinal chain to the Joint Tactical Information Distribution System. In addition, the software provides a UAV tool that captures live photos from UAV video, marks the target on a map within the navigation software, and stores telemetry data of UAV position and camera-pointing angles to allow target position "sweetening" using the Digital Position Strike Suite.

Background

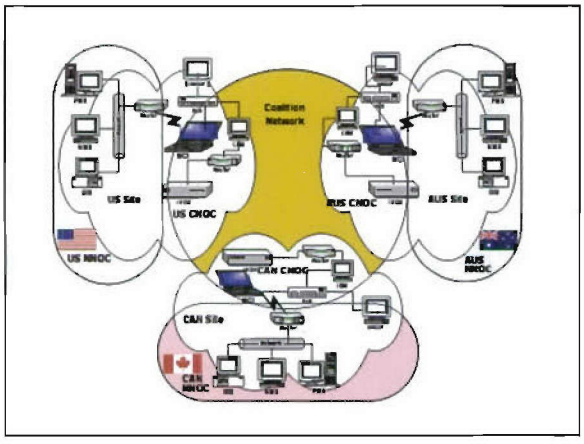
AFRL scientists assigned to the BAO kit program evaluated the use of off-the-shelf laptops; wireless networks; image compression algorithms; and small, camera-equipped UAVs to enhance both ground and aircrew situational awareness and engage time-critical targets. Additional development spirals are under way to increase communications, situational awareness, flexibility through the removal of cables, and use of small UAVs for targeting.

AFRL has a continuing program performed jointly by its Human Effectiveness, Information, Munitions, Propulsion, and Sensors Directorates, along with the Naval Air Systems Command (NAVAIR) and the Navy's Electronic Systems Command (ESC) to develop and apply their latest technologies cohesively toward a well-integrated, next-generation BAO capability. NAVAIR developed digital precision strike capability to generate precision-quality coordinates. ESC developed Cursor-on-Target extensible markup language schema capability to pass data across stovepipes.

AFRL Successfully Demonstrated CNMS to Australian Defense Acquisition Representatives

Payoff

AFRL supported a multinational demonstration of the Coalition Network Management System (CNMS) to flag officers from the Australian defense community. Successful military operations rely on the coordinated operations of multinational coalition partners. International participants require visibility of network assets within a coalition domain. Mission planners require the status of computing assets necessary to accomplish their assignments. A network operations center (NOC) must have the ability to dynamically and consistently respond to exterior and interior conditions.



Accomplishment

The Defence Science and Technology Organisation, Adelaide, Australia, with participation from the Canadian Research Centre and AFRL, hosted the CNMS demonstration. Australia, Canada, and the US formulated a research program to address NOC issues within the context of a CNMS. CNMS provides seamless management and control of a virtual Coalition Network Operations Center (CNOC) consisting of multiple enclaves with multiple participating nations.

During the demonstration, the AFRL Information Directorate showed how a virtual CNOC can be monitored and controlled using a policy management system that allows the coalition commander to change the posture of the information infrastructure based on external or internal threat changes. Additional capabilities demonstrated included secure passing of network management information across security domains, military quality-of-service mechanisms for ensuring priority Internet protocol traffic delivery, and management of low-bandwidth links by minimizing redundant management traffic.

Background

CNMS was demonstrated in all participating countries through the use of a complex operational scenario designed to showcase the new capabilities of the distributed NOC. Australian defense officials readily understood the need for a seamless information sharing capability within a coalition environment, and the demonstration successfully exposed them to new methods and ideas that will certainly seed and shape their thinking.

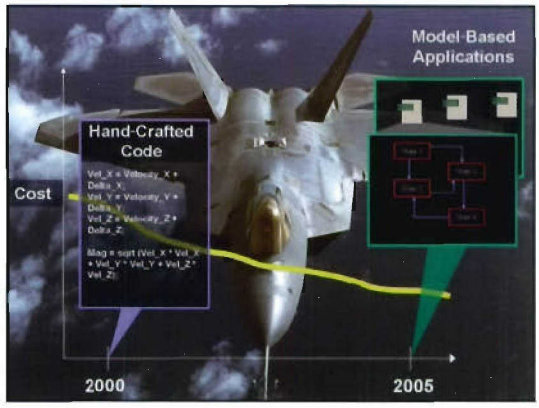
Embedded Software Technology Helps to Solve Critical Avionics Issues With F/A-22

Payoff

Model-Based Integration of Embedded Software (MoBIES) program tools were used to bolster system and software engineering practices on the F/A-22 program as part of an overall initiative to improve avionics stability. Under the management of AFRL, and funding from the Defense Advanced Research Projects Agency's (DARPA) Information Exploitation Office, the Secretary of Defense (OSD) commissioned an Avionics Advisory Team (AAT) comprised of about two dozen volunteer members from the science and technology community to identify and resolve major software flaws.

Accomplishment

This team of engineers and researchers from industry, government, academia, and the MoBIES project were assembled to look at the design of the F/A-22 software and hardware to determine what could be done to keep the system from having avionics anomalies every few minutes. As part of the AAT effort, technology from the DARPA MoBIES program was used to analyze communication resource utilization within the F/A-22 mission computer. This technology greatly increased the accuracy of timing and resource analysis compared to legacy techniques.



As a result, the design team was able to identify potential bottleneck areas earlier so as to avoid costly redesign. MoBIES technology was formally adopted by the F/A-22 program under the Common Integrated Processor 4G Mission Computer Upgrade program as the principle resource and timing analysis method. Additional MoBIES technology, including the Web-based Open Tool Integration Framework, was also brought into the F/A-22 program to allow other temporal and resource analysis tools to be used effectively. The F/A-22 ultimately recovered from stability problems and met the operational test and evaluation requirements for avionics uptime. The AAT was recognized for its hard work by the Secretary of the Air Force and OSD.

Background

The MoBIES project was started in 1999 with goals to expedite the development of reliable complex software for military applications through the customization of design tools and standardization of their interfaces. Following the success of the F/A-22 AAT, an F-35 AAT was commissioned in October 2003. AAT suggestions are currently being incorporated into F-35 design planning. A pilot program has been initiated to utilize MoBIES tools and technologies on the F-35 display management computer.

Technology Takes Autonomous Control of UAVs to the Next Level

Payoff

A flight test at the Dryden Flight Research Center at Edwards Air Force Base, California, demonstrated, for the first time, the control of an unmanned air vehicle (UAV) from a manned fighter. This was accomplished using an F-15E1 with its weapons systems operator (WSO) issuing a complex set of maneuvers to control the Joint Unmanned Combat Air System (J-UCAS) surrogate, a T-33. Software-enabled control (SEC) technologies will have long-term benefits on how UAVs are operated and controlled by the warfighter. The benefits include more UAVs controlled by fewer operators, aggressive maneuvers, air-to-air evasive maneuvers, autonomous vehicle avoidance, and voice input (natural language interface).

Accomplishment

For the demonstration, Boeing and its technology developers (TD) used the Air Force's F-15E and the J-UCAS surrogate, a T-33, to demonstrate a real-time open control platform (OCP) middleware, running several advanced controls applications from the TDs. AFRL is managing the Boeing-led OCP project under the Defense Advanced Research Projects Agency (DARPA) Information Exploitation Office's SEC program. With the J-UCAS test bed operating in an autonomous mode, the WSO in the backseat of the F-15E tasked the UAV through a series of flight maneuvers specifically designed to address challenging obstacles currently facing future UAVs. A few of the SEC-enabled transitional capabilities demonstrated include natural language tasking of UAVs, autonomous routing control, manned/unmanned anticollision formation flight, fault-tolerant control, dynamic UAV aircraft landing scenarios, as well as UAV tasking, operation, and trajectory optimization in a threat and time-sensitive target environment.

The OCP was the common thread enabling application-specific controls researchers to develop and test their algorithms in an end-to-end manner. Boeing provided the SEC program with experimental demonstration platforms containing the OCP in which the SEC TDs could exercise trajectory and path control of simulated and/or actual UAVs. The flight demonstration provided the SEC TDs an opportunity to test and demonstrate their research products in a realistic, real-time operational environment. TD controls applications for the demonstration are initially developed on the TDs' computers using the SEC analysis/design environment and are executed on the OCP infrastructure via the controls application program interface. Boeing rehosted and integrated the OCP and TD applications into airborne vehicles and ground-based vehicle simulations that were controlled via the identical OCP TD interfaces.

Background

The SEC program was started in 1998 by the DARPA Information Technology Office to change the way software and control systems are developed for embedded systems. SEC goals are to expand the operational envelopes of vehicles solely by improving their software middleware and control systems. There are 17 SEC contractors developing middleware and advanced controls applications to advance the state of the art in autonomous UAV operation and control. AFRL, DARPA, and Boeing, along with leading industry and academic teams including University of California-Berkeley, California Institute of Technology, University of Colorado, Honeywell, Massachusetts Institute of Technology, University of Minnesota, Northrop Grumman, and Stanford University, all contributed to the demonstration.

Engineers Fabricate Bumper Mounts for Forward-Deployed Robots

Payoff

AFRL engineers fabricated a bumper mount and ramp to assist personnel conducting explosive ordnance disposal (EOD) and counterterrorism activities in forward-deployed locations such as Operation IRAQI FREEDOM. The technologies overcome challenges related to the complicated assembly of ramps currently in use and show significant advantages over trailers, which have limited maneuverability. Deploying this technology should increase the safety of EOD personnel, who must sometimes manually approach improvised explosive devices (IED) when the current trailer and ramp limitations impede the deployment of a remotely operated system or robot.

Accomplishment

AFRL engineers fabricated a bumper mount and ramp, which allow deployed forces to carry small robots on the back of armored Humvees. The bumper mount and ramp were delivered to meet an urgent request from Central Air Forces and Headquarters Air Combat Command. The modified bumper mount and bifold, quick-release ramp allow the EOD personnel to transport and haul robots rather than using a trailer.

Background

AFRL Materials and Manufacturing Directorate engineers working at Tyndall Air Force Base, Florida, received an urgent and compelling request for a modified bumper-mount technology that would allow them to carry and transport small robots on armored vehicles. Robots are used for a variety of force protection, counterterrorism, and EOD operations including IED neutralization and reconnaissance. In just a few days, AFRL engineers identified a commercial off-the-shelf all-terrain vehicle (ATV) mount, which was compatible with a class 3 universal trailer hitch and could be used in conjunction with a ramp to mount and carry the robots.

AFRL teamed with Discount Ramps, in Westbend, Wisconsin, which provided services and six prototype bifold ramps. Engineers demonstrated that the improved ramps have significant benefits over those commercially developed and available to the commercial market. Battlefield advantages include durability and easy assembly and use, which warfighters require while in dangerous or life-threatening situations. In fact, engineers were able to drive a 750-pound ATV and its operator, the combined weight of which far exceeds the weight of a small robot, onto the ramp and mount it on a Humvee.

Additionally, officials from the Air Force Civil Engineering Support Agency have corresponded with Army officials about the technology. The Army may conduct a follow-on effort to explore the feasibility of using a modified dual-point mount to carry an ATV on armored vehicles without the use of a trailer.

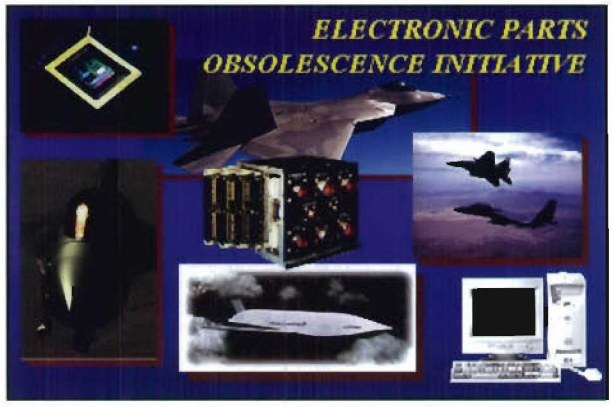
AFRL's Electronic Parts Obsolescence Initiative Produces Over $22 Million in Cost Savings

Payoff

The AFRL Materials and Manufacturing Directorate's Manufacturing Technology Division manages the electronic parts obsolescence initiative (EPOI). EPOI introduced processes and tools into the electronic parts obsolescence issue, saving the Air Force (AF) more than $22 million in a year. Additional savings will continue to increase in the future. The initiative's successes have kept the warfighter's aging aircraft fleet aloft in a safer and more affordable manner.

Accomplishment

Northrop Grumman, an EPOI member, successfully conducted the first of two pilot demonstration programs. They documented the savings by integrating a number of proactive practices and procedures and commercially available tools that resulted in huge cost decreases in areas such as materials, redesign, production, and sales. These savings stem from EPOI efforts to solve real-world concerns such as obsolescence prediction, life-cycle cost estimation, and commercial off-the-shelf reliability prediction. The second pilot program, with Lockheed Martin, is anticipated to document similar annual savings.



Background

Parts obsolescence, resulting from diminishing manufacturing sources and material shortages (DMSMS), has been a growing problem impacting mission readiness and has cost the government millions of dollars every year. DMSMS is prevalent in the AF's fielded and developmental systems, where the service life or development cycle is now longer than the manufacturing life of one or more of its components. There are program budgets that include millions of dollars annually to replace obsolete avionics hardware.

Several factors cause the electronic parts obsolescence. Chief among them is the decrease in the average life cycle of an integrated circuit due to technological advances, while the life cycle of America's weapon systems has increased. EPOI is about predicting and proactively managing obsolescence in the most affordable manner. Understanding the impact of system design and redesign cycles on obsolescence issues is paramount.

Yet another factor that contributes to obsolescence is a purely profit-driven one. Public consumption of electronics is far greater and more profitable, dwarfing military demands and making it less profitable to manufacture unique military parts. The three major areas to EPOI are decision and reengineering tools, application of commercially manufactured electronics, and pilot demonstrations.

AFRL Develops Grease Recommended for C-5

Payoff

AFRL developed low-cost, multipurpose grease, which received a positive evaluation from Air Force (AF) maintainers following nearly 1,529 airframe hours on the C-5 aircraft. The AF can solve several challenges related to wear, corrosion, and rust in the landing gear assembly of the C-5 using the new stable, low-cost, rust-inhibiting grease.

The new grease has proven that it provides superior antiwear and antirust performance and will provide a significant cost advantage because of reduced maintenance, parts replacement, and system failures. AFRL researchers also expect the grease to improve performance in other areas of the aircraft and replace many currently used military greases, therefore becoming nearly universal.

Accomplishment

AFRL Materials and Manufacturing Directorate experts conducted testing of the grease, which demonstrated water washout resistance, high-temperature, and high-speed performance. Equipment Maintenance Squadron specialists from Dover Air Force Base (AFB), Delaware, conducted a rigorous isochronal inspection of C-5 aircraft that were using the laboratory-developed grease. They recommended that the C-5 be converted to the new moisture-resistant, high-load-carrying grease, pending review of an interim status report and approval by the C-5 System Program Office.

AFRL personnel at Wright-Patterson AFB, Ohio, observed the aircraft parts and grease samples. After examining the parts and showing maintenance specialists test coupons with various greases to demonstrate grease performance, aircraft authorities agreed to change the technical orders for the C-5 to enact conversion to the new grease in all grease-lubricated aircraft applications. The consensus from Dover AFB's maintenance operation specialists was to convert to the new grease as soon as possible.

Background

In the late 1980s, AFRL researchers and Amoco contractors designed a unique lubricating grease, which was ultimately assigned the MIL-PRF-32014 military specification. The specification's rigorous performance requirements require the grease composition to include antioxidant, antiwear, and antirust ingredients for use in cruise missile engines.

A C-5 landing gear engineer at Ogden Air Logistics Center, Utah, approached AFRL to solve a dilemma resulting from the implementation of an expensive grease ($5,000 per gallon) recommended to solve corrosion and rust problems. The grease was not suitable for application and aggravated the problems. AFRL researchers analyzed wear and rusting challenges plaguing the landing gear of the C-5 and determined that MIL-PRF-32014 qualifying grease could offer improvements in the landing gear. The C-5 landing gear is regularly exposed to moisture, rain, air, bacterial decontaminants, and other corrosion-encouraging phenomena, which at times causes significant problems for operators and challenges for systems maintainers. While Amoco was unavailable to manufacture the grease, Nye Lubricants, a small business that specializes in specialty lubricants, commercialized a qualifying grease called Rheolube 374A.

AirBP also has a grease, Aeroplex 3214, qualified to the MIL-PRF-32014 specification. The two current suppliers were attracted to the larger volumes offered by use in the C-5 aircraft. MIL-PRF-32014 is expected to cost less than $100 per gallon and provide the desired improvement in performance over both the original grease and the contractor-recommended grease.

Powerful Ultrasonic and Eddy Current Capability Transitioned to Air Logistics Center

Payoff

AFRL Materials and Manufacturing Directorate engineers and the Aeronautical Enterprise Program Office's Aging Aircraft Division (ASC/AAA) transitioned enhanced ultrasonic and eddy current capability to the Oklahoma City Air Logistics Center's (OC-ALC) Nondestructive Inspection Production Team. This capability was integrated into the Boeing mobile automated scanner (MAUS), a large area automated inspection system currently used by OC-ALC. These new features equate to large maintenance cost avoidances for OC-ALC during aircraft periodic depot maintenance cycles.

Accomplishment

ASC/AAA funded the system's new features to automate additional time-consuming manual inspections and broaden detection capabilities for multilayer structures on the B-52, E-3, and KC-135 aircraft. This new capability of the fifth-generation MAUS (MAUS-V) is the result of a system architecture that provides greater depth resolution and higher data processing speeds. In comparison to MAUS IV, the MAUS-V has improved software features, such as data filter algorithms to highlight corrosion, and a new software database system to reduce inspection setup times. The enhanced architecture also provides a platform to support many other capabilities that require faster data processing rates, such as linear and phased ultrasonic arrays and multifrequency eddy current.

The new depth resolution ability will assist production personnel and engineers in distinguishing material anomalies from adjacent near and back surfaces on complex composite and metallic aircraft structures. The faster data processing capability of the MAUS-V will reduce some KC-135 inspection times up to 50%. In addition, the new database features of the MAUS-V will reduce some system calibrations and the setup times by 60% over the MAUS-IV.

Background

The MAUS-V software features allow operators to rescan ambiguous areas at higher resolution during inspections, so operators and engineers can make better decisions regarding structural disassembly and repair. In addition, new C-scan algorithms were incorporated to remove geometric feature effects and highlight areas of corrosion. The new database system uses scaling factors to reduce system setup and calibration times, which used to take up to 6 hours for some inspections. The improved MAUS-V hardware also provides better surface contouring around discontinuities such as button head fasteners.

The enhanced ultrasonic and eddy current circuitry of the MAUS-V yields faster data processing capability and better depth resolution to assist operators in distinguishing near-surface anomalies from surfaces. The advanced ultrasonic capabilities result from ultrasonic pulsing power greater than in previous MAUS configurations. This feature allows operators to inspect components with low sound attenuation properties and gives a better signal-to-noise ratio while improving resolution.

Advanced SIMS Analysis System Provides Highest Resolution Capability in the Air Force

Payoff

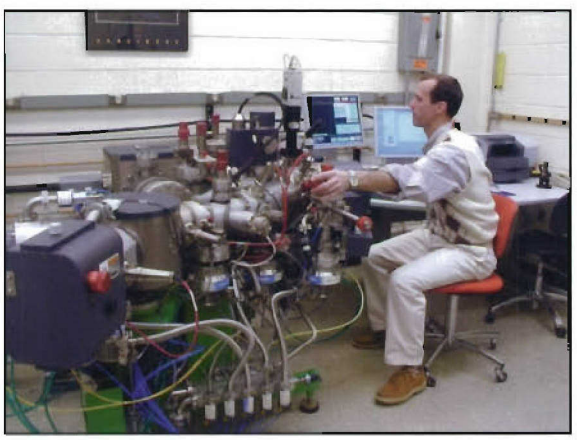
The AFRL Materials and Manufacturing Directorate, with assistance from the AFRL Air Force Office of Scientific Research, acquired a highly advanced materials analysis system, capable of analyzing the surface and in-depth composition of materials with sensitivities as high as parts per billion. The new Secondary Ion Mass Spectrometry (SIMS) system provides capability that dramatically increases the ability to identify and quantify dopants (materials added to crystals to change their physical properties), impurities, and contaminants in various materials. Applications include semiconductors, thin films, and many other materials of importance to current and future aerospace systems designed to support the warfighter and national defense.

Accomplishment

The newly acquired SIMS technology provides AFRL scientists and engineers with the most highly advanced in-house capability of its kind in the Air Force. The improved capabilities provided by this advanced materials analysis system will ultimately help improve the performance and reliability of critical aerospace systems and subsystems and will greatly enhance AFRL's reputation as a center of excellence for materials and manufacturing research and development.

Background

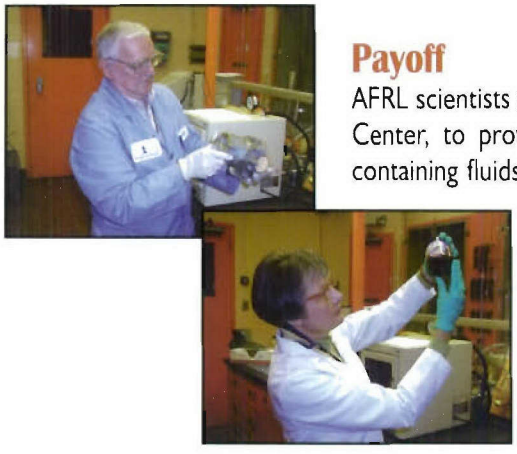
SIMS is a highly sophisticated analytical technique that combines focused primary ion beam bombardment with mass spectrometry of sputtered (ejected) secondary ions to achieve high sensitivity and high elemental selectivity. SIMS technology provides the much-needed capability for high-sensitivity, three-dimensional elemental analysis of molecular structure.



There are three basic types of SIMS. The first, static SIMS, is used for surface analysis. In this instance, low-energy primary ions are used to dislodge secondary ions from the surface layers. The secondary ions are then analyzed by mass spectrometry to produce a spectrum, which can be used to identify organic and inorganic species. The second type, imaging SIMS, is used for spatial analysis and involves scanning the primary ion beam over the surface to build an image that reveals the distribution of species. The third type is dynamic SIMS, which is used for depth analysis. Using this method, surface layers are progressively etched away by concentrating the primary ion beam into a small, concise area. This allows an analysis of the subsurface region, whereby depth profiles for different species are built by correlating the etch time with the intensity.

One of the principal advantages SIMS offers over other depth profiling techniques is its sensitivity to very low element concentrations. This is especially important in the semiconductor industry, where dopants are often present at very low concentrations. Some key applications of SIMS include education and research, chemical analysis of surfaces and mapping distribution of species, contamination analysis of thin films and surfaces, continuity monitoring of surface coatings, failure analysis of thin film devices, and bioactive surface development.

Scientists Prove Hazardous, Barium-Containing Fluids Unnecessary for Hydraulic Component Shipping and Storage



Payoff

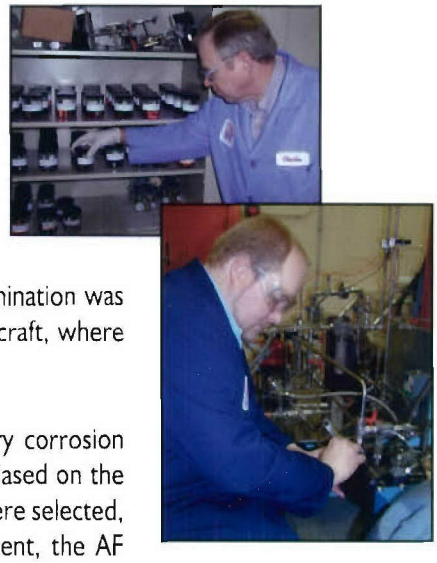
AFRL scientists and engineers completed a program, funded by the Aeronautical Systems Center, to prove that storing and shipping aircraft hydraulic components in barium-containing fluids provides no additional rust-inhibiting advantage over storing or shipping them in operational fluids. Following 3 years of extensive storage testing, AFRL personnel determined that using operational fluid in lieu of rust-inhibiting fluids would reduce the hazardous waste stream associated with the barium-containing fluids, eliminate a source of aircraft operational problems, and consolidate the number of fluids in the Air Force (AF) inventory.

Accomplishment

AFRL Materials and Manufacturing Directorate researchers from the Fluids and Lubricants Group developed and executed a pollution prevention program that suggests aircraft components can be stored in their operational fluids for lengthy periods of time without the onset of rust or corrosion. The results suggest the AF can eliminate the requirement for several thousands of gallons of barium-containing, rust-inhibiting fluids as well as the time and cost burdens associated with procurement and their disposal.

Background

The practice of using barium dinonylnaphthalene sulfonate (BSN), an additive in rust-inhibiting fluid, for the shipment and storage of aircraft components can be attributed to several military technical orders. In accordance with these technical orders, when a component is needed, it is removed from storage, the rust-inhibiting fluid is drained and discarded, and the component is installed.



However, because the rust-inhibiting fluid includes a barium-containing additive, environmental regulations have designated the fluid as a hazardous waste, which requires careful handling and additional disposal expense. In addition, BSN contamination was linked to operational problems, including sticking valves in Army, Navy, and AF aircraft, where components were not drained thoroughly before they were installed.

AFRL designed a pollution prevention program and surveyed a variety of military corrosion experts, aircraft maintainers, and system program offices (SPO) for their input. Based on the input and requests of those contacted, a test matrix was established, test articles were selected, and storage tests were begun. Based on testing results, and with SPO agreement, the AF modified a technical order for hydraulic equipment to allow for storage in operational fluid.

F-35 Program Adds CAI's Stresscheck™ to Analysis Software Suite

Payoff

The AFRL Materials and Manufacturing and Air Vehicles Directorates initiated and developed StressCheck structural analysis software as part of the Composite Affordability Initiative (CAI) effort. The F-35 Joint Strike Fighter program is including the tool in its accepted suite of analysis software. The analysis tool may minimize the amount of physical testing and its impact on costs and schedules.

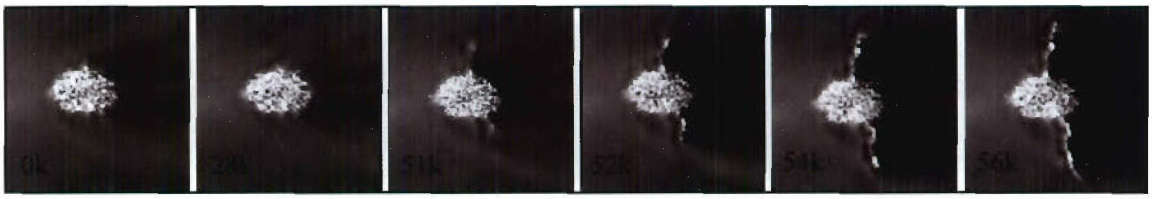
Accomplishment

AFRL, Boeing, Lockheed Martin, Northrop Grumman, and Bell Helicopter form the CAI team. The team developed and enhanced finite element software for analysis of composite structures. The StressCheck analysis tool shows a significant improvement in bonded and cocured joint strength prediction capabilities as compared to finite element analysis tools currently on the market.

Background

Preliminary applications on the F-35 inlet duct assembly joints and independent validation increased program confidence to use this tool on additional structures. Initially, the F-35 program evaluated the use of this software tool to analyze inlet duct assembly joints. As a result of the success of this initial application, the value of the StressCheck analysis tool was recognized for stress analysis of complex composite structural details, and the use of this software on the F-35 program has expanded.

Advanced Imaging Technique Reduces Risk of Structural Component Failures



Payoff

AFRL Materials and Manufacturing Directorate scientists and engineers developed and tested a new nondestructive evaluation (NDE) analysis technique for detecting fatigue cracks in structurally significant aircraft components. This new technique can be used to reduce the risk of catastrophic failure caused by corrosion in aircraft structural components. The technique provides an advanced crack imaging capability useful for microcharacterization of crack growth processes and provides a wealth of information on the microfeatures of the cracks initiated from pitting corrosion sites. This information is currently not available using any other advanced method.

Accomplishment

The new NDE analysis technique utilizes laser ultrasonic imaging to identify fatigue cracks initiated from pitting corrosion sites on material surfaces. AFRL researchers conducted a detailed, microscopic characterization of stress corrosion cracking (SCC) processes for electrochemically pitted aluminum specimens in a high-cycle fatigue environment. They acquired measurements using scanning laser ultrasonic detection of elastic waves propagating along the material surface. The research effort also included microscopic evaluations of crack extent, position, growth rate, and depth using near-field ultrasonic scattering signatures and examination of various pit depths, surfaces, and volume loss to ensure their conclusions were accurate.

Background

The effects of corrosion, fatigue, and cracking are becoming a major concern as aerospace systems are asked to perform well beyond their intended design lives. As this concern continues to grow, so does the need for better and more accurate NDE detection systems. Several studies have concluded that corrosion in structurally significant components can eventually lead to catastrophic failures if left unchecked. Corrosion fatigue and SCC are two of the primary mechanisms contributing to reduced aircraft service life. Although the detailed mechanisms are not yet well understood, it is generally accepted that localized corrosion pitting can act as a crack nucleation site, dramatically accelerating the onset of fatigue cracks and crack growth rates.

AFRL's NDE technique provides a capability for imaging cracks—an evaluation of the crack initiation sites as relative to the corrosion pit morphology. This may provide important insight as to the complicated interactions between realistic corrosion pitting sites and how they respond to applied stresses; material fatigue levels; and ultimately, crack initiation and growth processes. As an advanced NDE capability, the new technique proves very capable in imaging and characterizing the detailed features of surface-breaking cracks and should prove valuable in future efforts to understand and detect corrosion fatigue and stress corrosion cracking processes.

Materials Experts Develop Inspection Kit for Combat Training Pod Nose Cones

Payoff

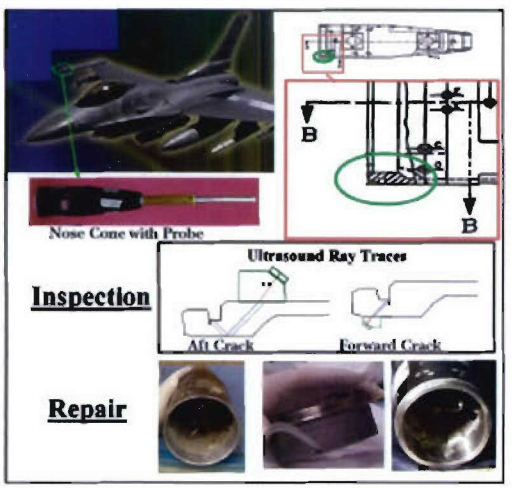
A team of engineers from the AFRL Materials and Manufacturing Directorate resolved a complex technical problem affecting combat training pod nose cones on fighter aircraft through a combination of failure analysis and nondestructive inspection development. The team's insight into design and materials characteristics enabled accelerated development of a low-cost solution to retrofit the existing nose cones with stainless steel collars, allowing the Air Force (AF) to trim costs significantly by implementing the retrofit component throughout the nose cone inventory. The laboratory-developed inspection kit provides an accurate, reliable means for locating cracks and determining their severity, while minimizing aircraft downtime and optimizing flight training opportunities.

Accomplishment

The investigative team, comprised of government and contractor materials experts from AFRL, analyzed what appeared to be surface cracks in several of the pod nose cones. The pods play a critical role in flight training; they record and relay aircraft positions and other information during training maneuvers. The team's investigation resulted in the development and expeditious transition of a portable inspection kit employing ultrasound technology and led to the successful design and development of steel collars to repair the remaining inventory of cones. The inspection kits provide a low-cost solution that could save the AF more than $2 million.

Background

Material integrity and component reliability are two of the most essential characteristics engineers design into jet fighter aircraft. In this case, a nose cone separated from an aircraft's air combat maneuvering instrumentation pod during takeoff. Technicians performed a cursory check, and during penetrant inspections identified several cones suspected of having cracks. The specific cone involved in the noted incident and the other suspect cones were sent to AFRL for a detailed analysis.



AFRL's nondestructive inspection team found the crack indications to be false in many cases, because surface anomalies (folds) trapped the penetrant and exhibited crack-like indications. Meanwhile, the failure analysis team discovered the root cause was an over-temperature condition caused by a coating process that negated the heat treatment of the material, leading to reduced strength and fatigue life. They ascertained this with simple conductivity and material hardness measurements.

Next, AFRL's nondestructive inspection team developed an advanced ultrasound inspection procedure that was extremely reliable and capable of detecting cracks in many different orientations and locations. They designed an inspection kit and transitioned the procedure to the field. During this transitional phase, the team inspected more than 150 nose cones to help the flight training squadrons keep functioning. They provided hands-on training to technicians in the field and also conducted a training session to prepare additional technicians from several AF bases. The AFRL team also assisted in the retrofit stainless steel collar design and brought in additional technical expertise from the Aeronautical Systems Center to aid with structural analysis. The team also developed an immersion ultrasound inspection for the retrofit design, inspected test articles before and after testing to validate the design, and conducted first article inspections on several cones to assure quality.

AFRL Develops Teleoperated Robotic Trenching Tractor

Payoff

Engineers at the AFRL Materials and Manufacturing Directorate designed, built, tested, and delivered a robotic trenching tractor, known as Robo-Trencher. The Robo-Trencher was delivered to support the 738th Engineering Installation Squadron's (EIS) combat engineering and installation teams. It established its value during Operation IRAQI FREEDOM when units were deployed to install and maintain fixed and deployable command and control computer and intelligence systems necessary for Air Force operations. The Robo-Trencher offers standoff capabilities to perform cable trenching and excavation missions in dangerous locations.

Accomplishment

The Robo-Trencher was developed to protect forward-deployed personnel responsible for performing cable trenching and excavation missions from hazardous situations, and to provide a teleoperated system to accomplish combat engineering installation activities. Each Robo-Trencher is equipped with a new laptop operator control unit with situational awareness and Global Positioning System tracking/locating capabilities. The system was delivered to the 738th EIS in less than 90 days and was tested by deployed units in the field. In addition, AFRL engineers created a remote kit to allow the squadron to retrofit all of the trenching tractors in its inventory.

Background

The 738th EIS team encountered two separate incidents with unexploded ordnance during manual trenching operations in Afghanistan. Afterwards, EIS contacted AFRL about robotic technologies. In order to meet the squadron's deployment schedule, AFRL engineers from the Airbase Technologies Division's Robotics Research Group began developing a short-order solution using the squadron's existing hardware.

The Robo-Trencher is a modified version of a trenching tractor--the Ditch Witch 7610, the standard tractor used by the squadron. Engineers involved in this project integrated robotic components that were developed for use with the group's all-purpose remote transport system, a technology used for force protection and active range clearance activities.

AFRL engineers are currently developing a second Robo-Trencher based on feedback from the unit. The improved system will include additional features such as heading-hold steering. The Robotics Research Group is also working to transition this technology to a system program office and private industry for future procurement and support activities.

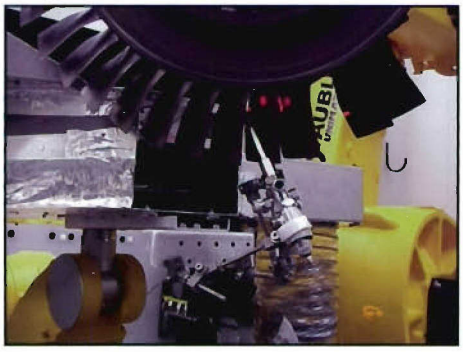
Extending Gas Turbine Engine Blade Life Saves Millions

Payoff

AFRL officials from the Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division, in partnership with LSP Technologies, Inc. (LSPT), of Dublin, Ohio, anticipate greater cost savings for the warfighter with their RapidCoater™ overlay application system, which introduces automation to the Laser Shock Peening (LSP) program. LSP technology is already credited with over $100 million in cost avoidance.

Accomplishment

AFRL and its partner, LSPT, designed and built an advanced laser system, the RapidCoater, to extend gas turbine engine blade life, thereby enhancing productivity and lowering costs. The RapidCoater system is a major innovation to the LaserPeen™ system and laser peening technology. It increases the process throughput by six to nine times, improves the reliability and repeatability of the process, and lowers the cost of processing by about 40%. The RapidCoater system is the ultimate automated method for applying the overlay coatings spot by spot at high speed. Essentially, it consists of a specialized airbrush spray nozzle, which is computer controlled to apply and remove the overlays at the specified times while a part is processed.



Background

Currently, General Electric Aircraft Engines (GEAE) has three operational RapidCoater production machines and is collaborating with the AF on an application for the F101, as well as the F110, gas turbine engine used in the F-16 Fighting Falcon. To date, GEAE has treated more than 20,000 F101 blades and transitioned the technology for application on the F110 engine, treating more than 2,000 blades. GEAE is working to apply the proven LSP technology to other engine components and commercial product lines in a cost-effective manner.

AFRL sponsored several efforts to demonstrate the diversity of LSP and the RapidCoater. General Research Corporation International, of Vienna, Virginia, experimentally demonstrated superior foreign object damage tolerance capability for LSP as compared with mechanical shot peening. LSPT successfully modeled elastic shock wave propagation and corresponding material effects of the LSP process on titanium alloys. The University of Dayton Research Institute used finite element analysis techniques to predict residual stresses induced by LSP. These successful efforts facilitated development of new applications for LSP.

LSPT and Pratt & Whitney are also expanding LSP applications to integrally bladed rotors and large components, initially for application in the F119 engine of the F-22 Raptor. This avoided a potential redesign and retrofit that would have cost as much as $10 million.

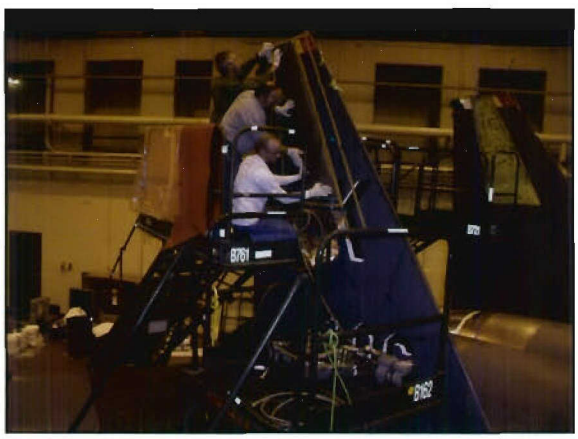
Bonding and Inspection Processes Strengthen F-15E Vertical Stabilizers

Payoff

Engineers at the AFRL resolved a serious and potentially expensive problem affecting the F-15E vertical stabilizers' stability and design life. Working with F-15 Engineering at Warner Robins Air Logistics Center, Georgia, AFRL successfully developed, demonstrated, and transitioned a bonding process and nondestructive inspection (NDI) procedure to ensure stiffening doublers remain attached to each side of both stabilizers. This innovative engineering effort provides greater safety for F-15E flight crews and extends a significant savings to the Air Force in vertical stabilizer replacement costs.

Accomplishment

AFRL's Adhesives, Composites, and Elastomers Team developed the new bonding process, and AFRL's Nondestructive Evaluation Team developed the thermography-based NDI procedure. The successful development and transition of the bonding process and NDI procedure ensures F-15E vertical stabilizer stiffening doublers continue to be a reliable and cost-effective structural reinforcement solution.



Background

The F-15E's vertical stabilizers require composite stiffening doublers (two per stabilizer) to reduce in-flight vibrations, which can reduce the life span of the stabilizers up to 25% due to fatigue cracking of the forward torque box. The original bonding process used to secure the doublers to the F-15E proved inadequate and led to extensive rework to replace the doublers that had become damaged or detached. Following multiple cases in which the stiffening doublers separated from the aircraft during takeoff or in flight, F-15 Engineering placed a hold on further modifications until a permanent fix preventing bonding failures could be implemented.

AFRL Structural Failure Analysis group identified inadequate preparation of the bond surfaces and excessive voids as the probable cause of these failures. The Adhesives, Composites and Elastomers Team then conducted numerous studies to address these deficiencies, resulting in the development of an entirely new bonding procedure. This new process improves the quality of the bond by drilling small holes through the doubler to allow trapped air to escape, improves the strength of the bond by grit-blasting the composite surfaces (similar to sandblasting but with very fine alumina grit), simplifies adhesive application by using premeasured kits, and reduces the repair time by applying heat to accelerate the adhesive cure.

The new NDI procedure implements a thermography inspection, that replaces the original tap testing and ultrasonic inspection, resulting in reduced inspection time and significantly improving the area of inspection coverage. The inspection of one doubler can be completed in about an hour using currently available equipment. The new bonding process will eliminate the need for rework (i.e., replacing doublers), since the NDI verified that the bonds on the test aircraft had almost no detectable disbonds (> 0.25 in. diameter) and displayed no disbonds near the doublers' edges.

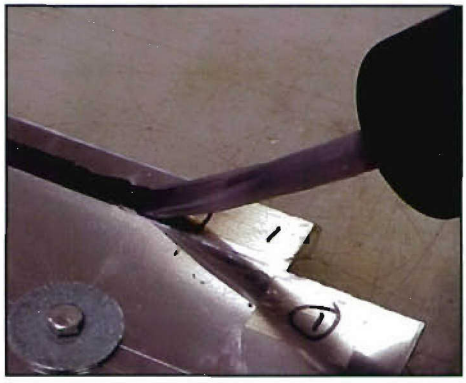
Advancements In Gap Treatment Materials Point to Improved Stealth Aircraft Maintainability

Payoff

AFRL researchers made considerable progress towards developing quick-cure, durable conductive gap treatment, and fastener fill materials for potential use by advanced aircraft. Gap treatment and fastener fill materials are commonly used on the outer moldline of stealth aircraft to conduct radio frequency energy away from gaps and seams and to maintain radar avoidability. The laboratory-developed materials, which include a broad temperature (-65° to 400°F) gap filler and a hot-melt fastener fill material, may be transitioned for use on aircraft in the Air Force inventory.

Accomplishment

The AFRL Materials and Manufacturing Directorate, working in tandem with General Electric, Northrop Grumman, and two aircraft System Program Offices (SPO), made substantial progress developing conductive gap treatment and fastener fill materials. When validated and transitioned, the materials could be used to improve the stealth capabilities of advanced aircraft.



Background

AFRL researchers are conducting several programs to address materials and processing needs for applications that require electrically conductive gap treatment and fastener fill materials. Gap treatments and fastener fill materials enable technologies for stealth and are a major priority of several aircraft SPOs.

Electrically conductive gap treatments must have high electrical conductivities and recoverable strain. Besides being flexible, gap treatment materials need to be resistant to common aircraft fluids. Gap treatment and fastener fill materials are susceptible to swelling when exposed to residual fluids left in the seams between aircraft surface panels. AFRL's near-term development programs identified electrically conductive material formulations, and engineers developed application procedures for more electrically conductive, quick-cure, durable gap treatment and fastener fill materials.

B-52 SPO Adopts Laboratory-Developed Fire-Resistant Hydraulic Fluid

Payoff

A fire-resistant hydraulic fluid developed by a team of AFRL experts completed a B-52 flight test and will be adopted for use in over 90% of the aircraft's components. The improved fluid's higher flash point and reduced flammability are expected to increase aircraft survivability and the operational safety of the B-52. In addition, thermal stability measurements and fluid film thickness data demonstrate that the improved fluid is usable in temperatures as low as -65°F, as well as in high-temperature environments for extended periods of time.

Accomplishment

AFRL scientists and engineers continually develop, promote, and encourage improved fluids and lubricants for application in the field for their safety, cost, and operational benefits to both the user and aircraft maintainers. With conversion of the B-52 to a fire-resistant hydraulic fluid, only a few Air Force (AF) aircraft still use a flammable hydraulic fluid. Experts are hoping that continued exposure to the benefits of the fire-resistant fluids will encourage other System Program Offices (SPO) to convert to one of the safer, superior-performing fire-resistant hydraulic fluids in the near future. B-52 systems engineers at Oklahoma City Air Logistics Center will conduct tests to determine if the landing gear struts and wingtip protection struts can also be converted to the fire-resistant fluid.

Background

Hydraulic fluids are a critical, safety of flight material for all AF aircraft. Hydraulically actuated mechanisms are responsible for a large number of aircraft functions, including highly sophisticated flight controls, landing gear operation, rudder flap control, and accessory door actuation. In addition, hydraulic fluids lubricate aircraft systems and remove operationally generated heat from components.

The hazards associated with the flammability characteristics of hydraulic fluids are well known. Hydraulic fluids are required to function in high-pressure hydraulic systems in the presence of a variety of ignition sources. Though fire-resistant fluids will burn, they are significantly more difficult to ignite and/or have a lower propensity to propagate a fire after ignition than a non-fire-resistant fluid.

Nonstructural materials experts from AFRL's Fluids and Lubricants Group dedicated significant research and development activities to preventing hazards caused by hydraulic fluids. Two synthetic hydrocarbon-based fire-resistant hydraulic fluids were successfully developed to meet the requirement and were compatible with the systems and design of aircraft, such as the B-52, that were using the flammable fluid.

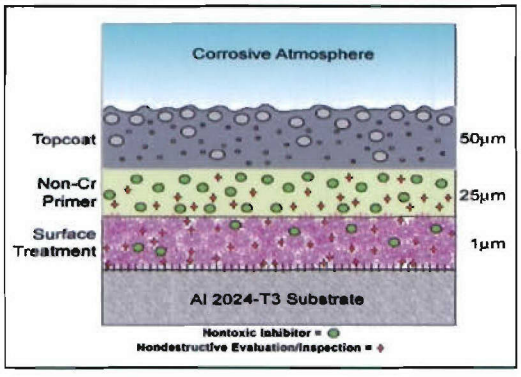
AFRL Scientists Develop and Transfer a Nonchrome Primer and Corrosion Inhibitor for Aluminum Aircraft Surfaces and Structures

Payoff

Scientists and engineers from AFRL completed a program to develop a novel rare-earth-element-based, nonchrome, corrosion-inhibiting primer coating for aluminum (Al) aircraft surfaces and structures. Replacing existing chromate-containing primer coatings with the new nonchrome primer will eliminate 90% of the hazardous waste stream and reduce disposal costs associated with the current chrome-based treatment, which is carcinogenic. After successful flight testing and subsequent approval by the Air Force Corrosion Prevention and Control Office, the Air Force (AF) can replace the current treatment and eliminate time and cost burdens associated with handling and disposal of the hazardous material.

Accomplishment

AFRL researchers developed and coordinated a technology develop-ment program to identify an environmentally friendly replacement primer treatment. AFRL conducted laboratory evaluations, material characterization, and salt spray testing, which showed the same performance standards as the current treatment. This program showed how a basic research concept can be developed and transitioned to industry in a relatively short amount of time.



Background

Due to the excellent corrosion-inhibiting properties of chromates (hexavalent chrome), chromate-based primers are used to control and mitigate corrosion in AF aircraft. However, hexavalent chrome is a known carcinogen, and the Occupational Safety and Health Administration has designated the material as hazardous, which requires careful handling and an additional disposal expense. Though a variety of nonchromium-based inhibitors have been developed and evaluated, never before has a treatment offered corrosion protection equal to the chromium-based inhibitor.

In 1999, AFRL scientists and engineers initiated the Environmentally Safe Aircraft Coatings program with the University of Missouri-Rolla (UMR) and Boeing Phantom Works, St. Louis. UMR focused its research on the corrosion-inhibiting properties of cerium oxide and other rare earth elements. The research program sought to develop both a conversion coating and a primer coating for a complete nonchrome paint system for aircraft. This program was one of the first development programs to develop the surface treatment and corrosion-inhibiting primer as a coating system.

Ultimately, the group developed a rare-earth-element-based inhibitor, which has shown corrosion resistance performance equivalent to that of chrome-based primers. Based on the results of characterization testing and evaluation of the rare-earth-element-based inhibitor, UMR entered into a developmental agreement with Deft Products, a major military coatings manufacturer, to produce the environmentally safe primer.

Tactical Mini Unmanned Air Vehicle Soars at CIDEX Event

Payoff

Micromunitions and small tactical unmanned air vehicles (UAV) that perform bomb damage information (BDI) and surveillance and reconnaissance missions decrease the risk of assets in a hostile environment. Research and development of the tactical mini UAV has proven beneficial in accelerating technologies such as micromunitions structural design; composite material manufacturing capabilities; and miniaturization guidance, navigation, and control hardware.

Accomplishment

The AFRL Munitions Directorate claimed victory at the Joint Combat Identification Evaluation Team's Combat Identification Exercise (CIDEX) event by successfully demonstrating an approximately 24 in. wingspan microair vehicle navigating through global positioning waypoints under supervised autonomy with real-time streaming video. With only minutes of training, war-game participants were fully able to utilize the system. Setup and teardown were accomplished in significantly less time than for other fielded systems.

Furthermore, field repairs confirmed the durability and robustness of the system. Results exceeded the expectations of users at the event. This momentous technology achievement will lead to a rapid Department of Defense (DoD) transition of several of the tactical mini UAV units.

Background

In pursuit of improving BDI and development of micromunitions, AFRL readjusted and responded to the need to augment the tactical UAV currently used by the Air Force Special Operations Command community. The tactical mini UAV was quickly developed in response to this direct user need and will allow the transition of technology from the laboratory to the DoD user in only 6 months, significantly reducing developmental costs.

The program continues to drive the need for power source innovation and future advancement of cooperative control algorithms and agile autonomous research for use in micromunitions. While serving as an important tool to the warfighter, the tactical mini UAV has the potential to serve many other agencies in search and rescue, targeting, and surveillance operations.

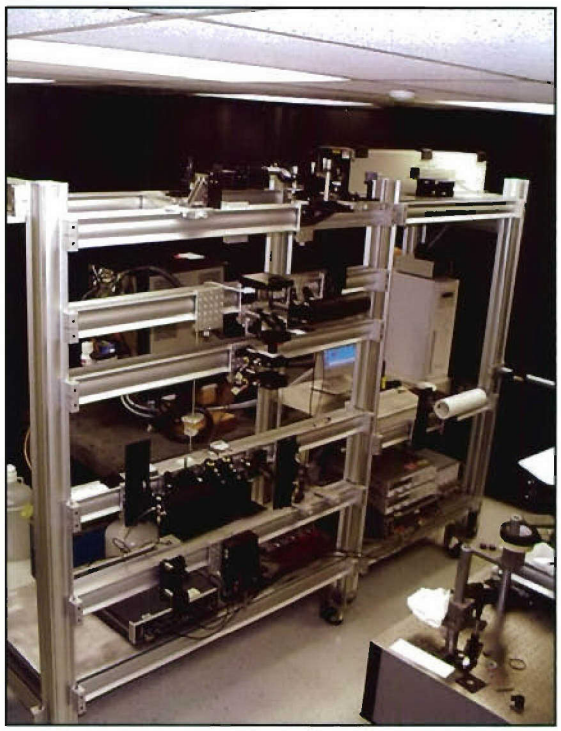
Monostatic Polarimetric Laser Reflectometer Development

Payoff

AFRL developed the first monostatic polarimetric laser reflectometer, which has a direct impact on the development of next-generation munitions seekers, as well as other for sensors capable of finding enemy assets. As a result of the effort, Dr. Dennis Goldstein, of the AFRL Munitions Directorate, published a 650-page textbook entitled *Polarized Light*.

Accomplishment

Dr. Goldstein and a team of four AFRL engineers and technicians led a 2-year effort to develop the first monostatic polarimetric laser reflectometer that can operate at 1.06 and 1.55 micrometers. The reflectometer provides a unique capability to measure target and background signatures at these wavelengths.



Background

The reflectometer is capable of characterizing the reflectance of both man-made and natural materials and producing complete Mueller matrices. A Mueller matrix is a 4 x 4 matrix that completely describes the polarization characteristics of the sample. An understanding of the optical properties of target and background materials is necessary to develop autonomous target acquisition capabilities for the next generation of munitions. Therefore, using the monostatic polarimetric laser reflectometer makes it possible to fully characterize target signatures under a variety of incident optical wavelengths and polarizations.

AFRL Transitioned Explosive Formulation With Significant Characteristics

Payoff

The AFRL Munitions Directorate transitioned an optimized explosive formulation with a patented wax-based binder system. The Army elected to incorporate the newly created PAX/AFX-196 into all of its self-propelled Howitzer artillery projectiles. By eliminating a proprietary foreign source of supply, AFRL researchers saved approximately $7 million in licensing fees and an additional $30 million in capital investment to outfit the designated Army ammunition plant with the ability to load M107/M795 shells with a plastic-bonded explosive.

Accomplishment

AFRL researchers chose to combine a nearly identical explosive formulation (AFX-194A) with a fluid energy milled (FEM) cyclo-trimethylenetrinitramine (RDX) produced at Holston Army Ammunition Plant. By incorporating the FEM RDX (coated with a plasticizer that eliminates additional drying and handling costs during processing of the composite formulation) into an optimized variant of AFX-194A, designated PAX/AFX-196, researchers produced a dramatic increase in manufacturability and yielded shock sensitivities nearly equivalent to those obtained in the original formulation produced with foreign source material. Additionally, to minimize the wax binders tendency to crack during thermal cycling, researchers altered the patented system to incorporate increased levels of plasticizer.

Background

AFRL's new explosive formulation was used in the Army M107 and M795 155 mm self-propelled Howitzer projectiles. Initially, the Army selected a standard Army/Air Force high-explosive formulation (PAX/AFX-194 Type I), recrystallized by a proprietary foreign source method that displayed excellent insensitive munitions characteristics.

However, during a 12-month aging study, the new formulation displayed shock sensitivities twice as sensitive as those previously determined when compared to baseline charges of PAX/AFX-194 Type I. Researchers determined the recrystallization process caused the problem.

Advanced Rechargeable Battery Program for Pointer UAV

Payoff

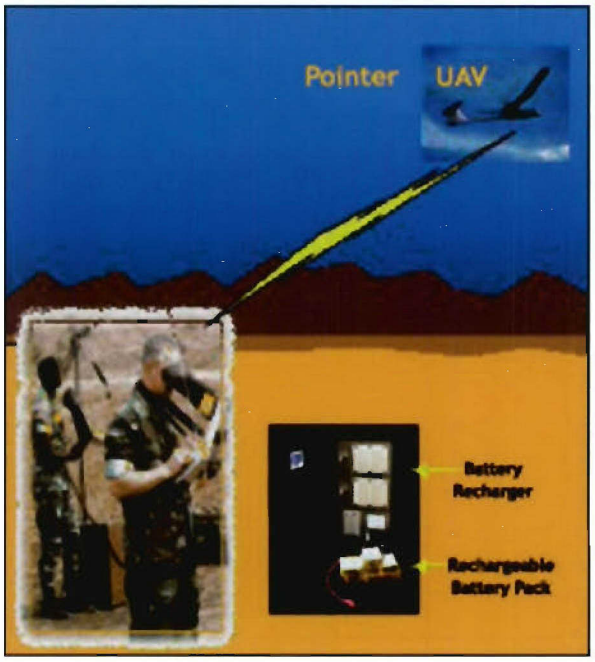
AFRL designed and built rechargeable battery packs in less than 45 days using the latest state-of-the-art lithium (Li) cells. The annual operating cost of rechargeable battery packs is far less than that of current disposable battery packs. The cost for one Pointer unmanned air vehicle (UAV) sortie using the old, nonrechargeable lithium sulfide (LiSO2) battery packs, compared to the new Li rechargeable pack, computes to a savings estimate of 60 to 1. Also, these new units will last for thousands of cycles, thus greatly increasing the field life of the system.

Accomplishment

The AFRL Munitions Directorate teamed with Compact Power, Inc., Colorado, and the AFRL Propulsion Directorate to develop a rechargeable battery pack for the Air Force Special Operations Command (AFSOC) Pointer UAV, in response to Operations ENDURING FREEDOM and IRAQI FREEDOM. Both the rechargeable battery packs and the recharging unit provide an increase in operational utility and solve a major logistical challenge to operate the Pointer UAV in austere locations.

The recharging units are equally important to the new battery packs. Designed for field use, they run off all common forms of alternating current and direct current inputs. This gives the warfighter the ability to recharge the packs from almost any power source.

The recharger will also charge the packs in the same amount of time it takes to fly a typical Pointer UAV mission, which means as one pack is being flown, another pack is being charged for continuous flying operations. Since one recharger is capable of recharging two packs simultaneously, one recharger and four battery packs will keep two aircraft flying continuously.



Background

The problem of battery packs became a critical issue as the war in Iraq began. The nonrechargeable LiSO2 battery packs were used in a wide variety of military equipment. Production capability peaked and shortages began to occur. The Pointer UAV is a primary tool employed by AFSOC personnel for tactical targeting and reconnaissance, and the shortage of LiSO2 packs impacted their operations in austere locations.

The solution to this problem was to design and build rechargeable battery packs in less than 45 days using the latest state-of-the-art 18650 Li cell. The commercial industry has seen the 18650 cells improve dramatically from 1600 mAhr to the current 2200 mAhr, with a potential to rise to ~2800 mAhr in the coming years.

Using 7 cells in a series per set and 3 sets in parallel, the combined 21-cell battery pack produces 6600 mAhr at a peak of 29.4 volts per direct current. The AFSOC Special Tactics Group is operationally flying the Pointer UAV and achieving greater increased flying time from the new rechargeable battery packs.

AFRL Develops Largest Precision-Guided Weapon

Payoff

The AFRL Munitions Directorate's Massive Ordnance Air Blast (MOAB) program developed and tested the largest, precisely guided air-delivered weapon in history. The 21,700 lb MOAB, an upgrade to the unguided 15,000 lb BLU-82 "Daisy Cutter," carried 18,700 lbs of explosive with precise accuracy to a predetermined target on an Eglin Air Force Base, Florida, bombing range.

The MOAB technology demonstration program showcased the ingenuity and flexibility of AFRL and its partners. Responding to high-level direction, new and modified large-weapon technologies were orchestrated into a cohesive system that met or exceeded all objectives within an extremely short schedule. The proven technologies lay the groundwork for possible future large-weapon programs and demonstrated a new and powerful warfighter capability.

Accomplishment

AFRL engineers rapidly and successfully designed, fabricated, integrated, and tested the MOAB weapon with support from the Defense Threat Reduction Agency; Natick Army Soldier Center; Naval Coastal Systems Station-Panama City, Florida; Air Transportation Test Loading Agency; McAlester Army Ammunition Plant; Detachment 1 of the 46th Test Wing at Hurlburt Field; Air Armament Center; and Dynetics, Inc.

The MOAB program incorporated innovative technologies to prove the feasibility of large-weapon operability, including the use of grid fins for flight control. The grid fins generated lower hinge moments and torque requirements, allowing the use of existing actuator components for weapon control. Existing flight computers and fuzing hardware were also leveraged, lowering development time and cost. The new extraction system incorporated existing hardware for familiarity and aircraft interface commonality, but with improved safety considerations and simplicity.

The fast-paced MOAB program went from development contract award to the completion of three highly successful flight tests within 9 months. The MOAB program culminated in the successful demonstration of a suite of technologies supporting large weapons. The MOAB provides a capability to perform psychological operations, attack large-area targets, or hold at-risk threats hidden within tunnels or caves.

Background

AFRL investigated the possibility of upgrading the large BLU-82 weapon with a guidance and control capability. Such an upgrade would allow the delivery aircraft to fly at a higher and safer distance for better survivability from the weapon's blast. It would also give the weapon greater range and far better accuracy, opening the door to additional target sets.

After several design iterations gave the weapon a more aerodynamic shape, the current configuration of the MOAB was born. Like the BLU-82, the MOAB rests in a cradle on an airdrop platform inside a C-130 aircraft variant. A parachute extracts the weapon, cradle, and platform, and the weapon is quickly released to maintain as much forward momentum as possible. The grid fins then release and guide the weapon to its target. During the flight tests, the MOAB detonated upon contact with the ground.

AFRL Collaborates With LSU Mechanical Engineering Students

Payoff

The AFRL Munitions Directorate collaborated with mechanical engineering students from Louisiana State University (LSU) to develop a new high-speed ballistic safety arena to support advancements in penetrator munitions research. As a result of the collaboration, five LSU engineering students benefited from a challenging real-life engineering problem, and the Air Force (AF) gained an efficient and effective design without pulling researchers from critical munitions research efforts. The collaboration resulted in the recruitment of one engineer by the Warner Robins Air Logistics Center at Robins Air Force Base, Georgia, as well as continued opportunities for AFRL to tap into a rich, creative atmosphere to infuse excitement into AF munitions development research.

Accomplishment

Mr. Kirk Herzog, of the AFRL Munitions Directorate, collaborated with a team of student engineers from the LSU Department of Mechanical Engineering capstone design course. The newly designed arena will allow AFRL to research, design, and develop high-speed penetrator munitions technologies to defeat hardened, fixed, and deeply buried targets. Not only does the new arena allow for increased velocity experimentation in concrete, it also provides additional arena length for soil penetration experiments. The new design is safer, reduces turnaround time (with consequently reduced operating costs), and provides much better diagnostics access.

LSU senior mechanical engineering students are required to take a two-semester capstone design course. Student teams are required to select a project, do the design work, and build and test the prototype, while providing biweekly status reports and two status presentations during each semester. The second semester is completed with the final presentation and technical report documenting the effort.

Mr. Herzog, an LSU mechanical engineering alumnus, requested and received approval to submit a project idea to the capstone course to conceive, design, and build a new arena to support high-speed penetrator research. Mr. Herzog proposed to collaborate with the university on the project, providing the students with a realistic project and freeing AFRL personnel to address critical research efforts. The proposal was a complete success for AFRL.

Background

The LSU senior design students presented an excellent conceptual design to AFRL and the Air Armament Center. The student team of Matthew Dowden, Shaun Lato, Richard (Luke) Millette, Steven Seiler, and Shane Thomas, advised by assistant professor Mr. Keith Gonthier, were able to provide an innovative concept and design drawings, and they began surveying the arena site (with help from range technicians) for construction prior to the conclusion of their second semester. AFRL provided the student design to a construction contractor, and with help from facility manager Mr. Chris Evans and site C-64B range controller Mr. Tony Gomillion, the arena is now complete. The contractor complimented features of the students' design that were borrowed from railroad engineering literature. The contractor commented that they would be able to apply the novel approach to future projects.

AFRL Develops First Flight-Weight RJC System for Air-to-Air Missiles

Payoff

AFRL successfully ground-tested the first flight-weight, reaction jet control (RJC) system for air-to-air missiles. During the test, four of the six reaction jet valves were actuated to duplicate a duty cycle that would be used on an operational missile during a close-in, over-the-shoulder target engagement. The test was a key risk reduction demonstration to develop next-generation tactical missiles with dual-range and/or dual-role capabilities.

Accomplishment

The AFRL Munitions Directorate-developed RJC system's size, weight, volume, response time, and duty cycle were demonstrated at the component level. The RJC technologies demonstrated in this test will provide future missiles with unprecedented maneuverability without degrading beyond-visual-range performance. This flight-weight system demonstration is an important milestone to the development of a single missile capable of performing both short- and medium-range missions.

Background

Honeywell Engines & Systems, Tempe, Arizona, developed the RJC system, integrated it with the nozzle section of an air-to-air missile solid-rocket motor, and conducted the test as part of AFRL's Missile Control Technology program. The RJC system is comprised of a set of six independently actuated hot gas valves. In operation, the valves redirect a portion of the motor exhaust to generate control forces in the pitch, roll, and yaw axes of a missile.

While the RJC technologies allow full three-axis control of a missile during extreme maneuvering, they have zero impact on motor thrust when not in use. This important combination is a capability that does not exist in either traditional thrust vectoring or jet-vane control systems. In contrast, the jet vanes used for improved agility on an AIM-9X Sidewinder reduce the thrust of the motor whether they are operating or not. This is acceptable for the Sidewinder since its short-range mission allows some range performance degradation without functional loss.

However, any control technology used to increase the agility of a medium-range missile, such as the AIM-120C advanced medium-range air-to-air missile, must not decrease its range capability. The RJC system is the only technology solution available today to address this problem.

The biggest technical challenge to the program was developing low-cost, lightweight valves to withstand the extreme temperature environment of an air-to-air missile motor exhaust. Due to this requirement, the use of heavy, expensive metals with high temperature and erosion characteristics, such as rhenium, would have made the technology unusable for tactical missiles. Thus, Honeywell kept the use of these metals to a minimum while making extensive use of silica-phenolic, carbide ceramics, and coated carbon composites.

AFRL Successfully Tests Ground Profiling Fuze Sensor for Unitary Munitions

Payoff

AFRL successfully tested the fuze air-to-surface technology (FAST) proximity sensor breadboard in a low-speed captive flight test (CFT) in McKinney, Texas. The FAST program is developing the next-generation fuze sensor for potential use with blast/fragment, penetrating, low-collateral-damage, and agent-defeat unitary warheads. The precise sensing capabilities that FAST provides will significantly improve the lethality and versatility of air-to-surface weapons.

Accomplishment

The AFRL Munitions Directorate gathered the FAST data in real-world conditions (including tower and CFT). They executed the tests in order to qualitatively assess launch-to-burst simulation validity to design parameters and identify any changes or system tweaks that may be necessary prior to the first iteration of form-factored electronics boards for the tactical nose mount configuration. The data will be used to support further development of the FAST proximity sensor algorithms.

AFRL conducted the CFTs with FAST operating in various modes and over various terrain (foliage and water included). The test results show a good match between the CFT data and the high-fidelity simulation. The CFT platform configuration was the Beechcraft Baron twin-engine aircraft. Researchers found the nose headlamp to be an ideal location for the FAST nose mount antenna. They cabled the antenna to the aircraft's breadboard electronics and controlled it via a notebook computer and an operator.

Background

The goal of the FAST program is to provide a distinct capability to the warfighter in two versatile forms: (1) a ground profiling, foliage penetration height-of-burst (HOB) upgrade for the DSU-33B/B proximity fuze sensor in a nose mount, tactical form factor to support the Targets Under Trees program, and (2) a precision HOB ground profiling and foliage penetration fuze sensor in a tail-mounted configuration.

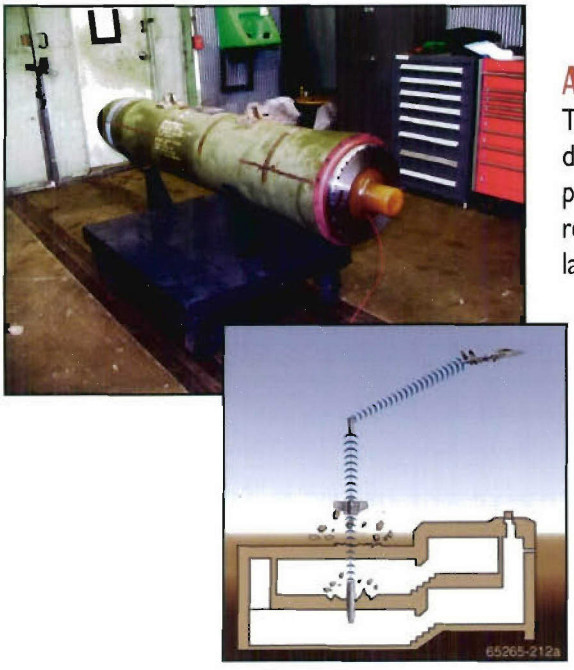
The modes of operation for the FAST sensor will be selectable HOB, near-surface burst, and penetration ground impact initial condition indication. The FAST sensor is highly resistant to electromagnetic countermeasures and electromagnetic interference environments, will operate in adverse weather and battlefield obscurants (including foliage), and is low cost. A wideband radio frequency transceiver using commercial off-the-shelf components was designed and developed and is being tested in relevant environments.

Increased lethality is integral in the drive for one-weapon-per-target operations, especially as weapons development moves towards smaller designs. The FAST fuze sensor will determine its height above the ground contour regardless of target and background structure and with minimal error in HOB selection. In addition, it will operate in weapon systems with 50–2500 meters/second closing velocities.

AFRL's FIBDID Program Tests Successful

Payoff

AFRL's Fuze-Integrated Bomb Damage Information Demonstration (FIBDID) program developed a wireless radio frequency (RF) transmitter for existing penetrator munitions. The knowledge of weapon performance will assist in assessing deeply buried target attack. Real-time data collected from the bomb as it penetrates will contribute to assessing strike effectiveness and determining whether a re-strike mission is needed.



Accomplishment

The AFRL Munitions Directorate developed a transmitter to accept data from the multiple-event hard-target fuze and transmit the weapon performance information to an aboveground repeater package. The repeater package will then relay the information to a receiver on the launch aircraft. The repeater will be ejected from the weapon as it approaches the target and will remain aboveground during the bomb's penetration. The repeater will receive the signal the bomb sends as it penetrates and will then transmit the information to the launch aircraft.

AFRL successfully accomplished a sled test on a BLU-109 penetrator, showing the transmitter hardware survivability through target penetration. Additional static tests successfully transmitted RF signals through simulated underground targets to the surface.

Background

Transmitted information will indicate whether the fuze made the correct decision to detonate at the desired location within the target and whether the bomb successfully detonated. It will also provide data on the actual construction of the underground target, including the number of layers and voids encountered. Mission planners will be able to use the information to plan subsequent attacks if the intelligence estimate used in the initial strike was determined to be incorrect, or if the bomb failed to detonate.

The repeater package must be ejected aboveground at a controlled height to allow the bomb to fully penetrate the target before the repeater package impacts the ground. An alternative is to tether it to the weapon to obtain a controlled distance between the repeater package and the target at weapon impact. If the repeater package can be made survivable, it will continue to function after its impact with the ground, providing continuous repetition of data for a more robust communication link to the aircraft receiver and other potential communication platforms.

MEHTF Successful in Navy High-Speed Ordnance Penetration Tests

Payoff

The drive toward faster, more accurate and capable weapons creates the need for intelligent fuzes capable of surviving high-impact conditions, thus increasing the ability of penetrating munitions to defeat hard and deeply buried targets. The multiple event hard target fuze (MEHTF) provides an accurate and low-cost solution for hard target defeat.

Accomplishment

AFRL teamed with the Naval Surface Warfare Center's Dahlgren Division to conduct high-velocity impact tests for the Navy's High-Speed Ordnance program. Two instrumented penetrators, each containing two intelligent MEHTF packages developed by AFRL, were successfully launched at high velocity from a cannon into layered targets consisting of concrete and air. The tests demonstrated MEHTF survivability and collected deceleration data during a high-speed hard target penetration event.

For the first test, the team programmed both fuzes to detonate on layer plus time delay to maximize the data collection. Both fuzes fired their inert detonators, resulting in a mission success. In the second test, the team programmed the forward fuze to fire the detonator in the second air gap and the aft fuze to function after counting layers plus distance. The forward fuze fired its detonator, and the internal data recorders in both fuzes yielded good media discrimination results. These penetration tests represent the most rigorous, long-duration, high-speed testing MEHTF has undergone to date.

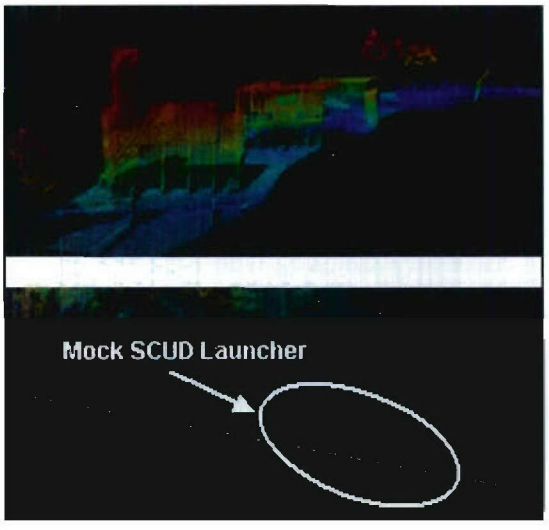
Background

AFRL initiated the MEHTF program to address anticipated fuzing needs for future penetrating weapons. AFRL researchers identified several future applications requiring a smart penetrating fuze. AFRL engineers identified specific technology limitations and structured the program to address them. These limitations include: surviving the severe shock environment associated with high-velocity penetration, using small penetrators that require reduced-sized fuzes, reducing cost to become competitive with time-delay fuzing, discriminating target media accurately, and providing a multiple event capability for complex multifunction warheads.

Infrared Sensor Provides 3-D LADAR Data

Payoff

The AFRL Munitions Directorate conducted a laser detection and ranging (LADAR) data collection flight test using the Burns Active Infrared (BAIR) sensor to support the Defense Advanced Research Projects Agency's (DARPA) Exploitation of Three-Dimensional (3-D) Data program. AFRL developed the BAIR sensor, an ultrahigh resolution, direct-detect scanning LADAR sensor. The test collected ultrahigh resolution data to be used by DARPA contractors for algorithm development, and demonstrated the LADAR hardware capabilities in a realistic environment.



Accomplishment

AFRL conducted the flight test at the US Marine Corps' Military Operations on Urban Terrain (MOUT) training facility at Camp Lejeune, North Carolina. The research team integrated the sensor package into a manned airship that flew over the MOUT site. The MOUT site, consisting of over 50 buildings and 40 vehicles, was completely mapped in eight passes. The target set included military vehicles and decoys, civilian vehicles, and a limited number of mock improvised explosive devices and personnel. Researchers altered target configurations and positions to determine the ability of target recognition algorithms to correctly identify articulations and scene changes.

Background

This highly successful test captured over 196 data frames over the MOUT site. Nominal scans contained 640,000 range points, which were converted through motion compensation to absolute 3-D points in Universal Transverse Mercator coordinates. Motion measurement was provided by a commercial off-the-shelf integrated Global Positioning System and Inertial Navigation System collocated with the LADAR sensor. Motion compensation was conducted off-line using laboratory-developed algorithms. AFRL is currently developing a real-time version of the motion compensation to allow in-flight viewing of compensated data.

Initial analysis validated the outstanding quality of the motion-compensated LADAR data against measured ground truth at the MOUT site. An additional registration refinement task to tightly register multiple frames of the same area is under way.

New Explosive Concept Reduces Collateral Damage

Payoff

Increased attention to the employment of precision weapons has decreased the occurrence of unintentional collateral damage; however, the development of new munitions to do the same has fallen behind, until now. AFRL's dense inert metal explosive (DIME) successfully demonstrated an effective mechanism to reduce collateral damage, helping the warfighter to prevent the loss of public support and, more importantly, the loss of innocent life.

Accomplishment

Survivability problems of conventional air blast transducers were encountered while measuring the close-in blast environment from DIME charges. In 2002, a specially designed Hopkinson bar gauge was utilized to obtain near-field blast measurements from a DIME charge. However, the 2002 tests produced data at only one distance at normal incidence.

AFRL's current 20-charge test series corrected that problem and produced reflected pressure and impulse data from a variety of distances and angles of incidence, facilitating a lethality analysis of the DIME concept. This data was used to create pressure and impulse maps that detail the near- and far-field magnitudes versus distance and angle of incidence, effectively validating the DIME charge as a low-collateral-damage munition.

Background

DIME concepts intentionally add heavy, nonreactive metal (tungsten, in this case) to an explosive composition. Upon detonation, the heavy tungsten particles are propelled outward in a cloud-like fashion with the advancing air blast pressure wave. Initially, the tungsten powder cloud travels in front of, and then with, the advancing shock. Then after a short distance, on the order of approximately 40 charge diameters, the forces of drag and gravity cause the tungsten particles to decouple from the blast field and fall to the ground or dissipate into the air.

The high-velocity tungsten powder cloud interaction with targets in the near field increases impulse and enhances lethality, while two mechanisms reduce damaging effects to collateral assets present in the far field. The first mechanism, the lack of fragmentation from a normal casing, eliminates fragment-induced lethality altogether. Secondly, the tungsten particles fall out of the air blast field with increasing distance. Since the tungsten particles fall out and the volume of high-explosive constituents are smaller in a DIME concept, far-field air blast is reduced significantly.

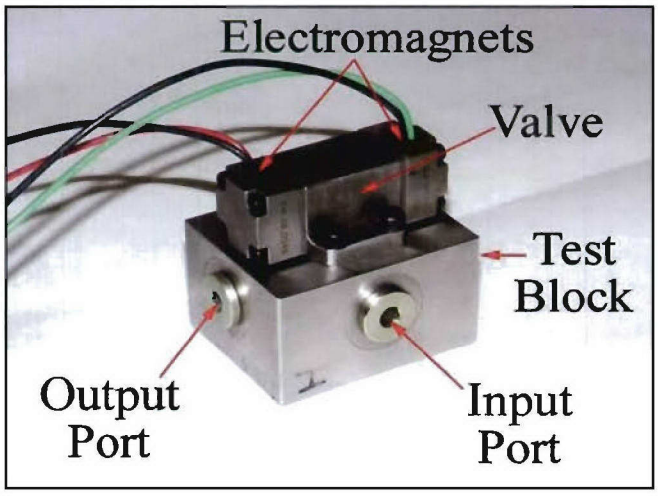
High-Response Fuel Valve Improves Performance and Reduces Costs

Payoff

The AFRL Controls and Engine Health Management (CEHM) team successfully managed the development of a high-response fuel valve that controls fuel system pulsations to improve combustion stability. This newly developed valve enables active control of the turbine engine combustion process, resulting in improved turbine engine fuel system stability.

Accomplishment

Dr. Al Behbahani heads the AFRL Propulsion Directorate's CEHM team, and Mr. Ken Semega is the program manager. AFRL recently accepted delivery of a new high-response valve that is capable of modulating fuel at a frequency as high as 650 Hz and changing the average fuel flow by as much as ±54% at the fuel delivery nozzle. The valve's flow capacity is up to 2,000 lbs per hour. This electromagnetic valve was tested in a 600°F environment. The benefit is a significant reduction in the combustion phenomenon known as screech, which can cause metal fatigue and premature engine failures.



Background

Combustion instability in a gas turbine power plant is the root cause of a phenomenon known as screech. In modern, low-emission engines, conditions are ripe for screech to occur, with attendant damage to internal components from metal fatigue and premature failure of internal thermal protective coatings. Damage from screech is difficult to assess and repair and frequently requires unscheduled engine entry, meaning the engine must be removed from the aircraft and disassembled, its affected parts replaced, and the reassembled engine tested to assure serviceable condition. This process is expensive and time consuming, and it seriously impacts the mission readiness of combat units.

Continuing research of screech and its effects has identified the potential benefits a high-response fuel valve can provide. The CEHM team worked closely with Mide Technology and Scientific Monitoring, Inc., to develop the valve under a Small Business Innovation Research program. This effort also included a cooperative agreement with Pratt & Whitney to perform verification and flight certification testing of the valve. If successful, this technology may be a candidate for transition into the operational fleet, where the potential cost savings and improved mission availability may be realized.

Remount of Global Hawk Generator

Payoff

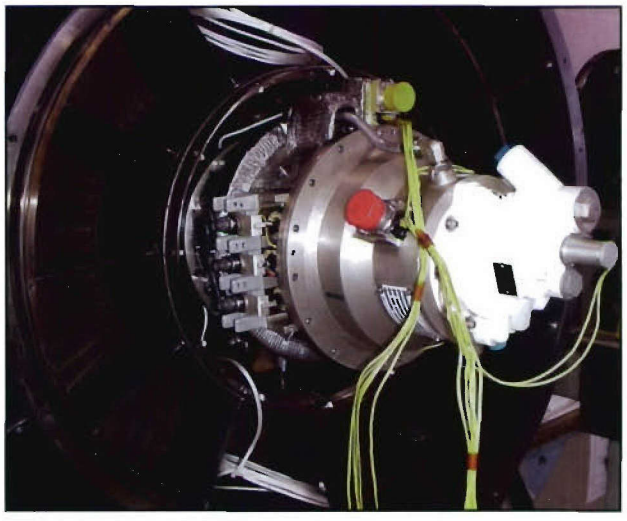
AFRL successfully developed of a Global Hawk AE3007H engine modification to permit direct-drive generator installation on the rear of its low-pressure fan spool shaft, located in the exhaust section. The engine's fan-spool-mounted generator enhances power extraction allowance at higher operating altitudes.

Accomplishment

The AFRL Propulsion Directorate, Allison Advanced Development Company (AADC), and Innovative Power Solutions (IPS) achieved the program goal of demonstrating increased baseline power for electric system loads and for in-flight restart capability. Initiated as a Small Business Innovation Research (SBIR) topic during 2000, AFRL led the team through the modification development process and system testing.

Background

SBIR contractor IPS built the generator and its control unit and performed first article testing at its facility. This testing focused on generator performance and response to the heat loads expected at the generator mounting location within the engine's exhaust tail cone. AADC designed the engine modifications necessary to install the generator on the engine spool drive shaft.



Generator heating problems were addressed by incorporating thermal shields and integrating the air-oil cooling to prevent generator overheating. The AADC test series at Rolls-Royce (Allison) included 60 hours of endurance tests, engine acceleration and generator step-load transient response, vibration scan, and generator thermal soakback evaluation with a 90-kilowatt generator overload. Following engine testing, the generator was returned to IPS for posttest analysis.

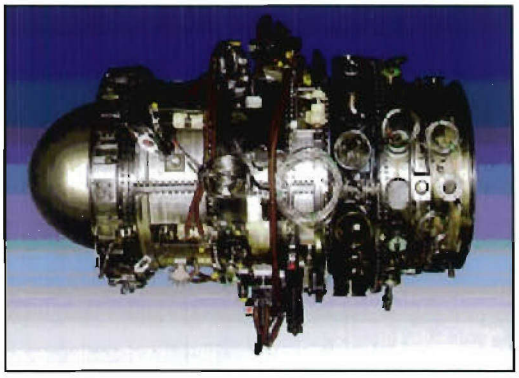
Turbine Engine Core Demonstrator Makes Propulsion History

Payoff

The AFRL Propulsion Directorate's Integrated High-Performance Turbine Engine Technology (IHPTET) test program demonstrated significant achievements in turbine engine design and development. The testing highlighted the IHPTET core demonstrator as one of the most advanced turbine engine technologies in the world.

Accomplishment

The world's most advanced turbine engine core demonstrator successfully completed 48 hours of testing at the Allison Advanced Development Company, in Indianapolis, Indiana. This testing validated the achievements of several advanced engine technologies required by the F136 (Joint Strike Fighter) engine. In addition to far exceeding thrust-to-weight ratio goals, the test demonstrated features such as compressor high-cycle fatigue reduction, high fuel-to-air ratio combustor design, advanced turbine cooling technology, and the use of hybrid ceramic bearings. The engine also demonstrated a ceramic matrix composite combustor lining, which allowed operation at steady turbine rotor inlet temperatures that were higher than ever achieved.



Background

AFRL's IHPTET program is managed at Wright-Patterson Air Force Base, Ohio. The program was established with the primary goal of doubling propulsion capability over conventional designs. The program is a national collaborative effort among the Air Force, Navy, Army, National Aeronautics and Space Administration, Defense Advanced Research Projects Agency, and turbine engine industry. The IHPTET demonstration was planned as a major milestone in the program to illustrate the capability to provide low-risk technology transition that will greatly improve engine performance, reduce costs, and increase the readiness and reliability of future engines.

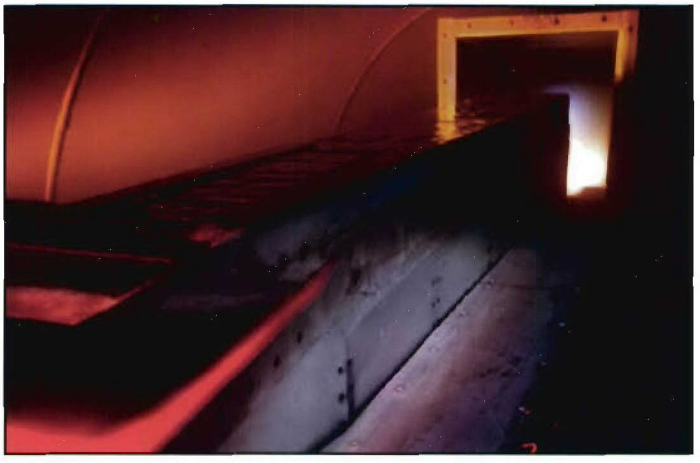
Initial Scramjet Fuels Testing Completed

Payoff

AFRL completed initial combustion/heat sink evaluation on alternative scramjet fuels. The JP-8, a low-cost, widely available aviation jet fuel performed well, making this fuel a viable option for high-performance, hydrocarbon-fueled scramjet engines.

Accomplishment

The AFRL Propulsion Directorate tested candidate fuels to be used in future scramjet engines. The tests, conducted at the United Technologies Research Center, in East Hartford, Connecticut, examined the endothermic cooling capacity of the fuels and evaluated ignition and operability characteristics at simulated Mach 5 conditions. The fuels tested include JP-7, JP-8, JP-10, and n-octane. Preliminary results indicated JP-8 could support operation in the high-performance range, reducing scramjet fuel cost, since JP-8 is widely available and relatively inexpensive. The National Aeronautics and Space Administration's Glenn Research Center financed these tests through its Advanced Propellants program.



Background

While today's top-performing systems typically operate in the Mach 0-3 range, new hypersonic systems could provide much faster response to adversary activities with the ability to attack time-critical targets at long range. Hydrocarbon-fueled scramjets that operate in the Mach 4-8 regime have near-term application to high-speed missiles and are an enabling technology for access-to-space programs.

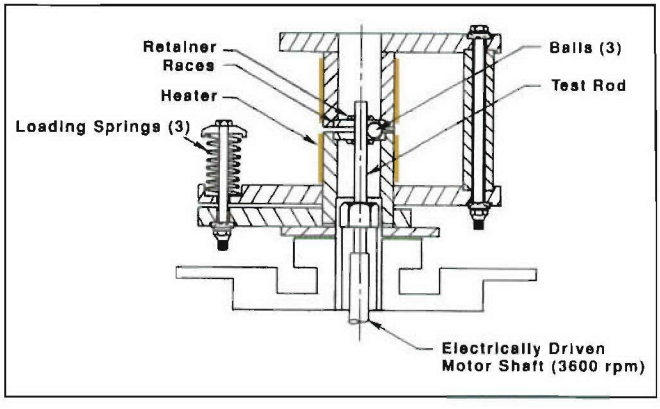
Bearing Tester Advancement Improves Turbine Engine Flight Safety, Reliability, and Performance

Payoff

The sustained performance of turbine engine bearings is one of the most critical factors in safe and reliable operation. The rolling contact fatigue (RCF) tester provides an excellent cost-effective screening technology to assure current and future generations of jet engines can achieve maximum engine service life. By pretesting aerospace bearings and lubricant material for compatibility, the Air Force's (AF) newest and hottest running jet engines can be protected from failure.

Accomplishment

The AFRL Propulsion Directorate designed and built an advanced RCF tester to evaluate turbine engine bearings and lubricants. The new RCF tester is used to assess material compatibilities and lubrication effectiveness by applying various bearing surface friction pressures at a rolling velocity of 3600 revolutions per minute at temperatures up to 700°F to simulate the most severe engine operating conditions.



Researchers evaluate the resulting effects of stress and fatigue on the test articles by using an optical microscope, energy dispersive X-ray analysis, or a scanning electron microscope. The test output times vary depending on the specific test objective and the materials being tested. Overall, the laboratory-developed RCF tester provides more than twice the bearing material and lubrication test capability than similar conventional testers available today. AFRL shared its test findings with other branches of the armed services as well as manufacturers of turbine engines, lubricants, and bearings.

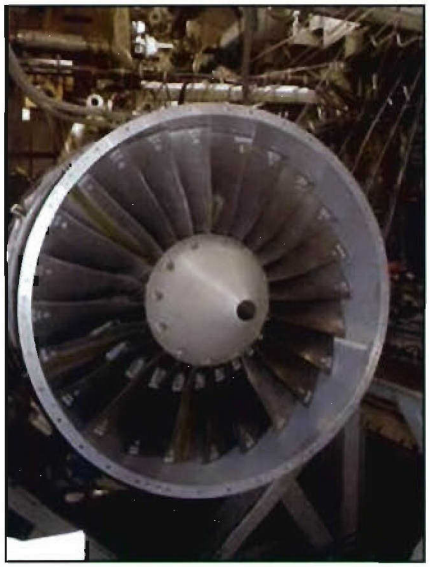
Background

AFRL and on-site contractor, Universal Energy Systems (UES), Inc., developed the RCF tester. The development work was planned under the Versatile Affordable Advanced Turbine Engines program for the USAF legacy and advanced turbine engines and commercial uses. AFRL and UES are pursuing a possible cooperative research and development agreement to produce and market the tester commercially.

Joint Testing Demonstrates Ability to Measure Stresses Inside Turbine Engine

Payoff

The capabilities of the fourth-generation nonintrusive stress measurement system (NSMS) were demonstrated during tests of an AE3007 turbine engine conducted at Allison Advanced Development Company, in Indianapolis, Indiana. The successful test opens the door for cost reductions for developmental engines and allows the US and the United Kingdom (UK) to exchange engine vibration data relevant to the Joint Strike Fighter engine acquisition program.



Accomplishment

The AFRL Propulsion Directorate's Propulsion Instrumentation Working Group, a government and industry collaboration, developed the US system as a replacement for older systems that could not measure the main drivers for high-cycle fatigue (HCF) damage in turbine engines. The test was a joint effort between the US and the UK to compare respective measurement systems used to support the investigation of HCF in military turbine engines.

The test demonstration compared the capabilities of the US NSMS and the UK system, known as Tip Timing, developed by Rolls-Royce. During the test, these novel systems each monitored the same components simultaneously while conventional direct-reading strain gauges recorded stress measurements. The test results showed that the two new systems were quite comparable to each other and that both were very close to the strain gauge data. This joint compatibility testing was a rare opportunity for the US and UK to compare stress measurement systems at a single reference point to better support future turbine engine development programs.

Background

Over the past several years, the HCF program has been responsible for providing solutions for many difficult turbine engine developmental and in-service fatigue-related failure problems. Compatibility testing of the NSMS and the Tip Timing stress measurement systems is yet another notable accomplishment under this program.

Turbine Engine Smoke Measurement System Completes Validation

Payoff

The AFRL Propulsion Directorate and the University of Dayton Research Institute (UDRI) collaborated to design, fabricate, and verify a new automated turbine engine smoke sampling system. This system supports the Versatile Affordable Advanced Turbine Engines (VAATE) program for the Department of Defense joint services, National Aeronautics and Space Administration, Department of Energy, and industry.

Accomplishment

The laboratory-developed system performs in-house evaluation of turbine engine gaseous emissions. This capability includes combustion tests to measure gaseous emissions from turbine engines in order to assess the pollutant characteristics and fuel efficiency of advanced engine design concepts. The new smoke sampling system has a number of unique features that are critical for obtaining accurate VAATE program assessments of turbine engine soot emissions. The system also increased productivity by providing a threefold decrease in the time required for test data collection.

Background

Traditionally, AFRL sampled turbine engine smoke, an aerosol-containing soot, by utilizing a 1970's technology engine smoke emission analyzer. This testing was limited to applying the same standard used to test aircraft engine emissions for commercial certification. However, during the past 3 years, scientists performed rich burning experiments involving VAATE research to reduce particle matter (soot) emissions. The tests seriously strained the conventional smoke data collection process. AFRL and UDRI overcame this challenge in their successful development and validation of the new system.

Army Benefits From AFRL Fuel Research

Payoff

AFRL developed a JP-8 turbine engine fuel additive that improves the fuel's thermal stability by 100°F. The additive effectively increases the fuel's capacity to operate at high temperatures without risk of increased thermal oxidative deposition (coking). Reduced coking results in improved engine reliability, more efficient combustion, longer on-wing operating times, and reduced fuel-related maintenance.

Accomplishment

AFRL Propulsion Directorate researchers assisted the Army Research, Development, and Engineering Command (RDECOM) team in the development of the implementation plan and initial start-up of the additive test. The RDECOM team began a 2-year trial of the additive in its helicopter fleet at Fort Rucker Army Post, near Dothan, Alabama. The Army estimates future use of JP-8+100 in Army aviation resources has the potential to save $35 million annually in engine maintenance costs and provide a corresponding improvement in operational readiness rates. The trial period will be used to validate and update this estimate.

Background

AFRL fuel researchers initially developed the JP-8+100 additive in the mid-1990s. It is currently used in US Air Force fighters, tankers, and some cargo aircraft and has been previously transitioned to the National Aeronautics and Space Administration, Denmark, and the Canadian military. The Tampa Police Department, Florida, also uses the additive technology (as Jet A+100) in its helicopter patrol fleet.

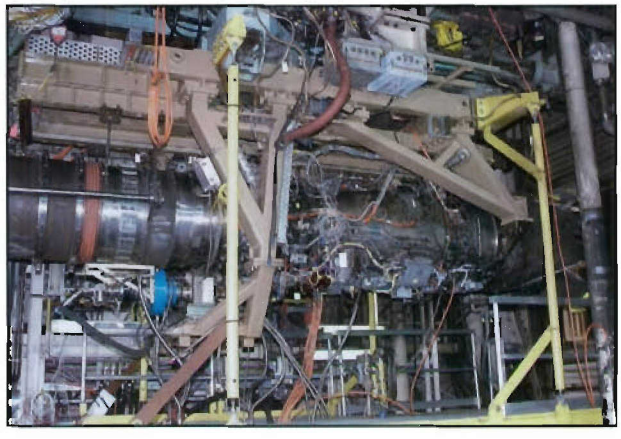
IHPTET Program Demonstrator Engine Testing Successful

Payoff

The AFRL Propulsion Directorate's Integrated High-Performance Turbine Engine Technology (IHPTET) program completed its most successful year of demonstrator engine testing. Demonstrator test engines have been highly successful in establishing technology baselines and setting precedents for further improvements. The technologies demonstrated by these engines will be transitioned to advanced aircraft engine development programs such as the Joint Strike Fighter.

Accomplishment

Among the IHPTET demonstrator engines tested were those developed by Allison Advanced Development Company, Honeywell, Pratt & Whitney, and General Electric. Some of the demonstrated technologies included four-stage high-pressure compressor stability, high-pressure ratio core-driven fan, fan damping, rotor dynamics, and advanced compressor aerodynamics. In some cases, the tests involved the highest temperature demonstrator core engines ever run. In addition, the core engines demonstrated capability to achieve a 48% increase in thrust-to-weight ratio, a 23% reduction in production costs, and a 19% reduction in maintenance costs.



Background

The IHPTET program began in 1987 as a collaborative effort between AFRL, the Department of Defense, the National Aeronautics and Space Administration, and industry, with the primary goal of doubling propulsion system capability by 2005. The technologies developed by the program are intended to be used in the design of future manned and unmanned turbofan, turboshaft and turboprop, and expendable propulsion systems.

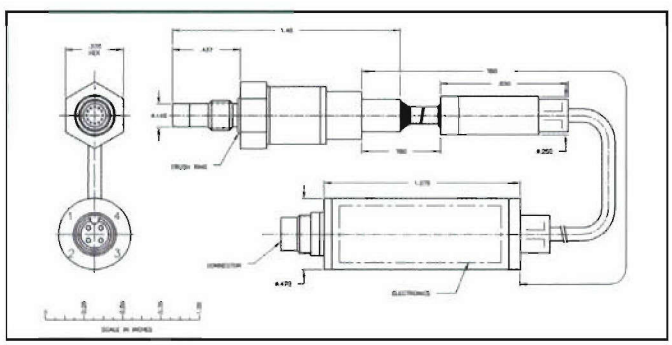
AFRL Develops Turbine Engine Augmenter Screech and Instability Detection Transducer

Payoff

High-performance military turbine engines are often equipped with augmenters, also known as afterburners, to provide increased levels of thrust. Augmentation levels are limited in part by the onset of debilitating combustion instabilities known as screech and rumble. The transducer shown above was developed as a key technology for screech and instability detection and avoidance.

Accomplishment

AFRL and its industry partner, Kulite Semiconductor Products, Inc., completed a very successful Small Business Innovation Research Phase I program resulting in the development of an advanced engine acoustic/screech transducer. Utilizing the latest research information, a single, rugged, highly accurate high-temperature transducer was developed to suit the severe environment within an augmenter. The sensing elements were fabricated using Kulite's new "leadless" silicon-on-insulator technology, which enables the sensor to operate at temperatures in excess of 1100°F, maintain a natural frequency of 200 kHz, and withstand shock and vibration in excess of 200 g.



The transducer's ability to provide both highly accurate static and dynamic pressure data is made possible by the use of piezoresistive technology and microelectromechanical systems fabrication procedures. As part of this effort, the suitability of electrical, material, and packaging technologies for high-temperature and vibration environments were evaluated. Additionally, an amplifier circuit/assembly facilitating the processing of both the static and dynamic signals simultaneously, with extremely high resolution (.01 psi), was developed and successfully evaluated. Excellent accuracy results of less than 1% over the entire temperature range were demonstrated during testing. The design performance established the feasibility of producing engine-ready prototypes.

Background

AFRL conducts research and exploratory and advanced development programs in air-breathing engine science and technology. Development of the engine acoustic/screech transducer is one of many ongoing programs being executed to improve turbine engine design, control, and health management concepts.

AFRL Technology Improves Predator B Survivability

Payoff

AFRL developed an improved paint scheme for the second-generation MQ-9 (Predator B) unmanned air vehicle (UAV). Engineers designed the improved paint scheme specifically for the Predator B and its operational environment to reduce visual detection, acquisition, and/or tracking, therefore improving its survivability.

Accomplishment

The visual detection range of an air vehicle is highly dependent on its paint scheme, flight profile, environment, and location of the observer (input conditions). The AFRL Sensors Directorate used an optical encounter model to effectively evaluate the trends that would be caused by this set of input conditions.

Given the conditions provided by the system program office (SPO) and experience gained by a previous effort for the Predator SPO, a number of possible paint schemes varying in design (e.g., single or multiple grays) and reflectance values were defined. A simple pattern was chosen because detection, not camouflage, was the primary interest. The paint scheme providing the best overall performance was a medium to dark gray paint at 20% on the bottom of the UAV and a 37% reflective paint on the top portion. AFRL determined and recommended to the Aeronautical Systems Center the improved paint scheme, which was adopted and sent to the Air Combat Command for approval.

Background

The Predator B aircraft required an appropriate paint scheme to optimize operations in a tactical environment. The original Predator UAV paint scheme was not designed to minimize visual detection. Since many antiaircraft systems rely on visual detection, acquisition, and/or tracking, repainting the Predator B with a scheme designed specifically for its operational environment would greatly improve its survivability.

AFRL was requested to evaluate and recommend an appropriate paint scheme based on its visual signature and vulnerability to human or optically aided antiaircraft fire. They performed a study that outlined findings concerning the vehicle's visual signature during normal operating flight paths and altitude levels. AFRL used an optical encounter simulation model to study six potential paint schemes, and the conclusion was that a two-tone gray scheme offered the best protection for all given parameters.

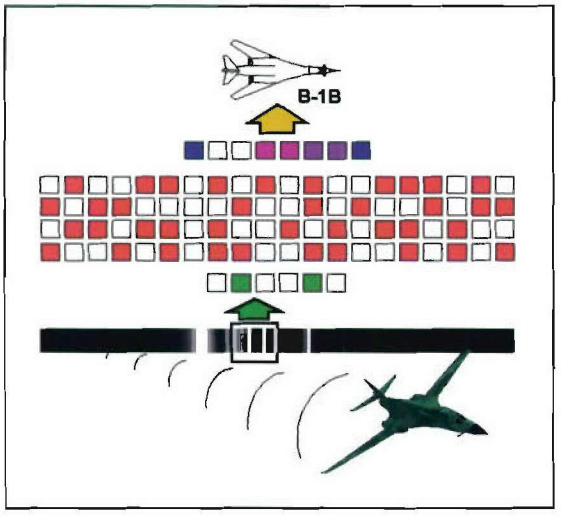
Dynamic Programming Network Assists in Automatic Target Recognition

Payoff

An AFRL scientist, working with the AFRL Air Force Office of Scientific Research, developed a procedure for finding the optimal sequence of actions to reach a solution to a Markovian decision process (MDP) problem. This could allow the warfighter to classify targets faster than previously possible.

Accomplishment

Mr. James Morgan, of the AFRL Sensors Directorate, designed and implemented a network of elements that dynamically programs values associated with the states of subsets of other network elements. He applied three progressively more complex networks to solve pattern recognition problems of increasing difficulty. The application displays the states of the network and data from the problem as it is being solved.



Background

In an MDP, every action leads to a state in which another set of actions are available or to an end state that has a known value. During several trials, states with known values pass their values to prior states until the values of all possible states are established. The vast number of states in real-world applications constrains dynamic programming. Seeking only the information necessary for solving the problem, the number of states encountered diminishes considerably.

In automatic target recognition, sequentially examining features of importance and retaining only the information required to choose future states are functions that can be dynamically programmed. Such metadynamic programming in which the choice of functions is dynamically programmed can be constructed as an MDP with partially observable data.

The multiplicity of functions to be programmed suggested a network implementation. A significant impact to the Air Force is probable, as it will become possible to classify up to 10,000 targets per second with a variety of sensors or combinations. This is particularly true for those aircraft that currently use high-performance computers on board.

AT3 Program Successfully Demonstrated

Payoff

Responding to a critical warfighter need to accurately locate time-critical targets such as surface-to-air missile systems, the AFRL Sensors Directorate and the Defense Advanced Research Projects Agency jointly funded the Advanced Tactical Targeting Technology (AT3) program. The program successfully demonstrated the capability to passively detect and accurately geolocate enemy air defense radar systems faster and more precisely than currently achievable.

This technology bridges the gap between reactive suppression and preemptive destruction, a key requirement for air dominance. The direct benefit to the warfighter centers on improved standoff capability to quickly and accurately target precision-guided munitions to destroy mobile air defense units.

Accomplishment

The AT3 program team built and tested a prototype system capable of acquiring, recording, and correctly identifying the highest priority threat emitters verified through open-air flight testing. The AT3 system used multiple radio frequency sensor platforms communicating via tactical data link to detect and geolocate enemy threat emitters. A significant part of the test evaluated the system capability against multiple, identical threat emitters operating at nearly the same frequencies. The team verified system performance incrementally at various stages of development and integration—first in the laboratory, then through ground tower testing, and finally, open-air testing.

The system successfully acquired and identified all threat emitters tested during single and multiple emitter tests. The system successfully demonstrated a flexible, open-network approach incorporating multiple platform detections, thereby producing more accurate geolocation of combat threats.

Using a concept of operations with far-reaching potential for the warfighter, the program further demonstrated that nondedicated aircraft could simultaneously satisfy suppression of enemy air defense (SEAD) and electronic support measures (ESM) requirements when equipped with a sensor interconnected by a single, real-time network.

Background

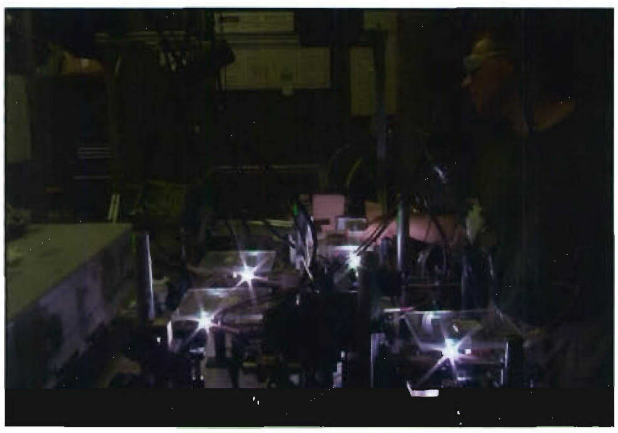
To give the warfighter the ability to replace the current tactic of reactive suppression with aggressive preemptive destruction of enemy threat emitters, military aircraft in the current and future inventory must support the SEAD and ESM mission.

The AT3 program successfully demonstrated that current and future platforms equipped with an ESM sensor and processor interconnected by a single, real-time network can concurrently satisfy dedicated mission and SEAD requirements. AT3 was the first program to allow a shift from reactive suppression to preemptive destruction. This shift provides passive, cooperative-platform, emitter geolocation of sufficient precision and timeliness for lethal SEAD targeting from a nondedicated platform aircraft with a system requiring minimal aircraft modification.

First-Ever MHz Rate Wave Front Measurements Demonstrated

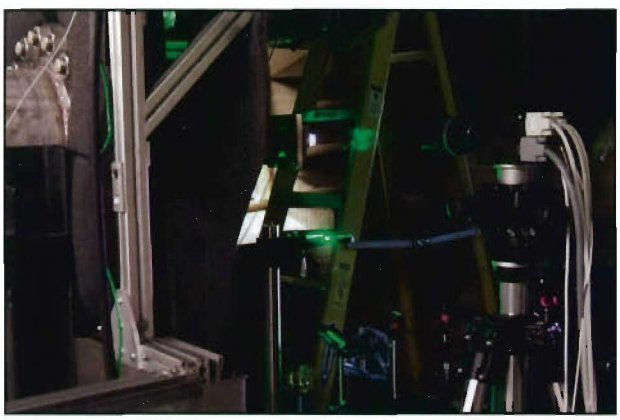
Payoff

In collaboration with the AFRL Air Vehicles Directorate, the University of Dayton, and members of the Gas Dynamics and Turbulence Laboratory at The Ohio State University (OSU), the AFRL Sensors Directorate completed experiments that demonstrated ultrafast, MHz rate wave front measurements and simultaneous MHz rate flow visualizations. This represents a significant advance over the most recently reported aero-optic imaging measurements.



Accomplishment

The design and development of an MHz rate Shack-Hartman wave front sensor was integrated with a MHz rate pulse burst laser system designed by the OSU team to obtain simultaneous MHz rate wave front measurements and flow visualizations. The experiments demonstrated the first-ever real-time measurements of full-scale aero-optic aberrations. The ability to measure aero-optic aberrations will positively impact system development of airborne lasers, active/passive optical sensors, laser communications, and other systems that pass optical signals through transonic and fast subsonic airflows where the effectiveness is limited by aero-optical distortion.



Background

The Air Force has a critical need for improvements to flight-based, electro-optic sensing and directed energy systems. Sensors such as active laser radar, or LADAR, are used for strategic and tactical surveillance, identification and targeting of threats, and battle damage assessment. High-power lasers can be used to direct large quantities of energy to a remote target, resulting in an extremely responsive, timely, and flexible weapon system.

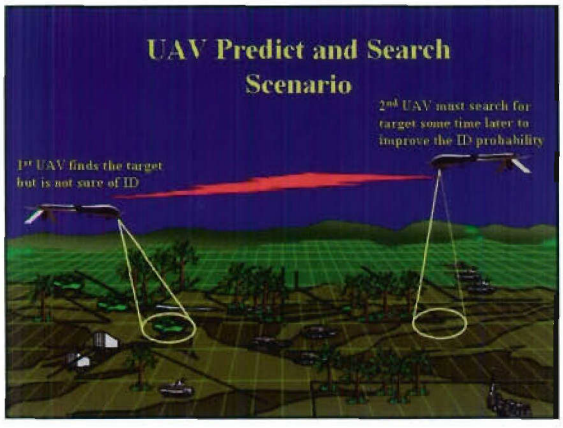
Aero-optical distortion is, in general, a fundamental factor limiting the effectiveness of current systems. In typical tactical flight conditions, the efficiency with which laser energy can be directed to a potential target is estimated to drop by 30% to 70% after passage of the laser beam through the typical turbulent shear laser of the transmitting window on the aircraft. The ability to predict and perhaps control such distortion offers the possibility of recovering a large portion of this energy loss.

Algorithms Developed for UAVs

Payoff

An AFRL scientist developed a successful program of basic in-house research in the areas of robust stochastic estimation, prediction, and search algorithms for unmanned air vehicles (UAV), cooperative control of UAVs, and fuzzy dynamic systems for state estimation. The improvement in state estimation using the continuum model approach provides greatly improved tracking and navigation system accuracies.

These improved estimate accuracies provide significantly better tracking continuity and enable pilots to hit targets sooner and more accurately. Another benefit of the continuum model approach is that the computational burden is reduced by at least 67%. This approach can be implemented and transitioned to the warfighter quickly and inexpensively, because it requires only a simple software upgrade of the aircraft or platform avionics.



Accomplishment

The AFRL's Sensors Directorate's development of novel prediction and search algorithms for UAV munitions solved the problem of an air vehicle that detects a mobile target using its own sensor(s) but delays attack. After detection, the air vehicle takes additional looks, thus producing target-state estimates (position, velocity, acceleration, and so on). Later, the same or another air vehicle views the target area. This time, the target is not detected. The challenge is to reacquire the target using an optimal prediction and search strategy. Updates to position likelihood are made using hospitability maps, which characterize a given target's mobility at each point on the earth's surface.

AFRL also created an estimation algorithm based on a continuum of models, instead of the discrete set found in multiple-model (MM) methods currently used in target tracking and other Air Force applications. The new method reduces the biases and "chattering" (an alternating error signal due to model switching) effects that exist in most MM tracking algorithms.

Background

Normally, ground personnel complete the process of prediction and search using maps. Prediction and search capabilities developed by this research make an autonomous approach feasible, giving rise to many improvements to warfighter capabilities. For instance, UAVs with this new capability to search and attack enemy targets autonomously gives the Air Force the ability to prosecute time-critical targets. These concepts and methodologies for autonomous prediction and search have been transitioned to The Ohio State University and the University of Dayton for further study. This is the first step to transition this remarkable technology to weapon systems.

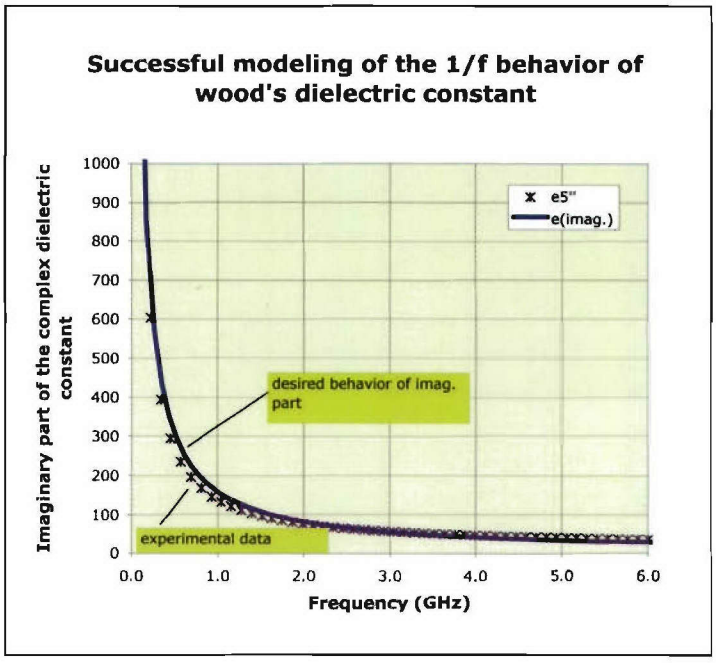
Progress Achieved in Scale Models for TUT Program

Payoff

During research supported by the AFRL Sensors Directorate and the Targets Under Trees (TUT) program, Dr. Andrew Gatesman, of the University of Massachusetts at Lowell, demonstrated the capability to construct electrically accurate scale models of live wood over the 5–70 MHz frequency range. Electromagnetic scale modeling is a well-established technique that has only recently been applied to wood in support of the Air Force TUT program.

Accomplishment

Dr. Gatesman is able to form synthetic aperture radar (SAR) images of targets concealed in forested terrain on a secure and cost-effective indoor range. Scale model radar measurements yield results identical to real-world targets at wavelengths scaled down proportionately with the model. The scale model radar operating frequency is the real-world frequency multiplied by the scale factor, in this case 87. Thus, real-world frequencies in the 5–70 MHz range correspond to scale model frequencies between 0.4 and 6 GHz.



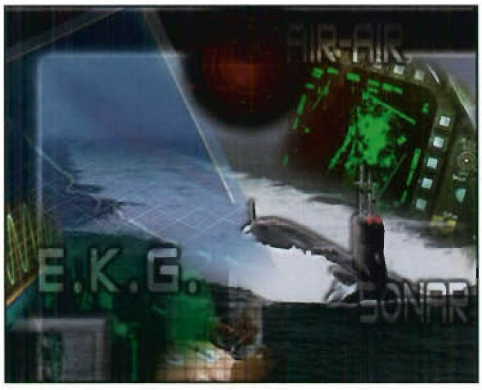
Background

The geometry and dielectric properties of the radar scene determine the electromagnetic scattering. Therefore, accurate modeling of the dielectric constant of the trees is critical to accurate image formation. Since real foliage-penetrating SAR systems uses waveforms that extend over tens of MHz, the scale models must accurately mimic the dielectric constant over that range. Dr. Gatesman used a wax-based modeling material loaded with carbon fiber to achieve the required loss properties.

Automatic Target Recognition of HRR Signals

Payoff

An AFRL Sensors Directorate scientist developed an original approach to create powerful features to use in automatic target recognition of high-range resolution (HRR) radar signals. This approach is a methodology for developing wavelet-based classifiers using HRR signatures.



Accomplishment

HRR is the key waveform being considered to enable feature-aided tracking on all future airborne and space-based moving target indicator systems. AFRL's research demonstrates iterative selection of wavelet features for classification significantly outperformed the classifiers processing only the raw data, which is the current state of the art for HRR classifiers. Experimental identification technology allows 20 out of 60 signals to be classified from the best raw data feature, but using the wavelet-based classifier, the best feature can classify a remarkable 50 out of 60 signals. Applied to wavelet features, the developed methodology greatly increases classifier performance from 77% to 90%. The chance of misidentifying targets is therefore greatly reduced, resulting in a lower probability of fratricide or friendly/neutral casualties.

Background

Wavelets are used to represent data or other functions. In wavelet analysis, the scale used to observe data plays a specific role because wavelet algorithms process data at different scales or resolutions. The HRR waveform that was the focus of this breakthrough is, therefore, and will continue to be, instrumental in operational moving target identification of both airborne and ground targets. Using this approach, the probability of correct classification was significantly increased over baseline approaches that use the entire signature for classification.

Predator UAV Antenna Placement Determined

Payoff

The AFRL Sensors Directorate collaborated with the Aeronautical Systems Center/Reconnaissance Aircraft System Group and the AFRL Information Directorate to determine which antenna placement configuration would best serve the system performance in the Predator unmanned air vehicle (UAV). The group's placement decision for optimum system function affects 70 operational aircraft as well as subsequent production models.

Accomplishment

The AFRL team conducted a flight test at Edwards Air Force Base, California, where a Predator UAV flew a predetermined course. By measuring the receive energy from the predator and knowing the position of the aircraft, researchers generated a set of performance curves for different antenna configurations. They compared receiver signal calibration with the antenna configurations to determine which one best served the system performance. The Predator UAV is now being manufactured according to their recommendations.

Background

Antenna measurements require known locations to transmit and receive antenna orientations along with power levels and distances. The flight testing telemetry is processed into measured receive signals to determine signal strength independent of the test conditions. The range-independent values provide an equal basis of comparison between antenna configurations. Previous technology included the baseline design and placement of the antennas and resulted in intermittent and/or low-performance communication signals.

Angle-Doppler Compensation Algorithm Invented

Payoff

An AFRL scientist's contribution to bistatic airborne radar altered the way systems will be designed and developed. This achievement is especially important in wide-angle bistatics, incorporating air and space assets, where complicated iso-Doppler contours demand angle-Doppler compensation (ADC) to collect even the smallest amount of similar training data, essential in adaptive weight computation. This research enables fieldable bistatic sensors development, in addition to exploratory algorithm development.

Accomplishment

An AFRL scientist invented an ADC algorithm that permits real-time processing to be viable in adaptive bistatic radar systems. This was done by understanding the geometry involved in the adaptive algorithm formulation and implementation for bistatic radar clutter rejection. This concept permits compensation of geometrically induced nonhomogeneities, which result in dispersion of ground clutter in the phase spectra.

Background

Since the late 1980s, researchers have focused on the nonhomogeneous nature of ground clutter without considering the geometric effects on radar returns. Robust algorithms that cope with dynamic and nonhomogeneous ground scatterers masking weak target returns are essential to achieve near-optimal performance in a space-time adaptive processing-based airborne or space-based bistatic radar.

Realizing geometry's impact on training data selection in adaptive bistatic airborne radar when examining two-dimensional amplitude and phase spectra, researchers examined from a systems engineering perspective the effects of geometrically induced nonhomogeneities in training data. The proposed algorithm was invented because of this analysis. This algorithm is capable of altering the phase spectra of clutter in the training data as a function of bistatic range, transmit/receive position and velocity, and location of the cell under test, while leaving the amplitude spectra unchanged. This technique alters the way in which algorithm development for adaptive weight computation in bistatic airborne radars is pursued.

Vibration Isolation System Enables Airborne Laser

Payoff

The airborne laser (ABL) is expected to be the Air Force's first operationally fielded directed energy weapon system. The ABL will provide theater missile defense to protect US troops anywhere in the world. The ABL would not perform as required without a system for controlling dynamic vibration and precise registration of multiple optical benches. Under a Small Business Innovation Research (SBIR) Phase II contract, the AFRL Space Vehicles Directorate and CSA Engineering, Inc., designed, built, and tested an airborne suspension/vibration isolation system.

Accomplishment

AFRL and CSA Engineering developed an isolation system that stabilizes and aligns the resonator optics of the ABL segment, the primary component of the system. The innovative system comprises frictionless, ultrasoft air springs and high-performance magnetic actuators. The result is extremely precise position control coupled with an ultrasoft ride for ABL optics, an unprecedented achievement in meeting such competing requirements. The isolation system solves the critical issue of providing multiple, extremely stable platforms for sensitive laser optics during all possible flight conditions while operating in the presence of large laser-induced vibration, acoustic, and shock disturbances.

High-power laser technology from AFRL allows the system to fly a stable optical bench within the aircraft that can operate in a real-world environment. One of the most complex isolation systems ever built, it successfully demonstrates the advanced technology required to meet the stringent ABL requirement. The optical bench isolation system (OBIS) simultaneously meets the unprecedented requirements for rejecting the large unwanted vibrations affecting the system combined with the competing requirements for extremely precise registration of multiple optical benches spaced more than 50 ft apart in the ABL aircraft.

This successful SBIR Phase II project has transitioned to a $6 million follow-on contract to build a ground demonstrator and the OBIS, which will be a critical enabling component in future operational ABL and other directed energy systems.

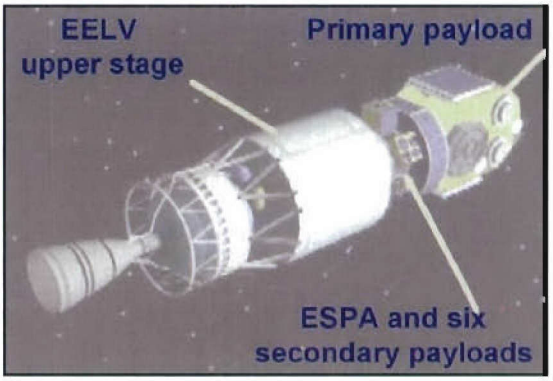
Background

One of the most critical issues with ABL development has been the simultaneous stabilization, alignment, and vibration isolation of the laser segment resonator optics during flight. The requirements for rejecting unwanted vibration and the competing requirements for extremely precise registration of multiple optical benches in the ABL aircraft is unprecedented. The ABL will not operate properly without precise vibration control. The SBIR Phase II effort was arranged to solve this mission-critical problem.

Low-Cost Ride to Space for Secondary Satellites

Payoff

As part of the Small Business Innovation Research (SBIR) program, the AFRL Space Vehicles Directorate and CSA Engineering, Inc., are developing a standard secondary payload accommodation on the evolved expendable launch vehicle (EELV). Researchers expect the SBIR adapter technologies to have a tremendous impact on future spacecraft programs, such as increased access to space for space experiments and small satellites, increased availability of secondary payload launch opportunities, and huge cost savings. AFRL's development efforts will help pave the way to changing the launch paradigm, allowing full utilization of small satellite technology within the US.



Accomplishment

AFRL identified large unused payload margins on the majority of Department of Defense (DoD) EELV (Delta IV and Atlas V) manifests. Taking advantage of this existing unused payload margin, EELV secondary payload adapter (ESPA) will increase access to space for small satellites and space experiments. By sharing mission integration and launch expenses, the cost of space access can be dramatically reduced.

ESPA mounts on one primary spacecraft and up to six secondary spacecraft on a Delta IV or Atlas V launch vehicle. The first flight of the ESPA will be on the STP-1 mission, launched on a Delta IV medium. The primary payload on this mission is orbital express. The success of this mission will ensure the availability of a secondary payload capability on the EELV class of launch vehicles.

Background

The Air Force needed to develop a low-cost ride to space for secondary satellites. The low-cost launch of secondary satellites (up to 400 lbs) can greatly increase the number of missions that are flown, thereby increasing the advancements of space-based technology and increasing the warfighters' ability to detect and destroy. The DoD, National Aeronautics and Space Administration, universities, and industry share an interest in using small satellites to perform space experiments, demonstrate new technology, and develop operational systems.

Despite the benefits of small satellites for certain applications, infrequent launch opportunities and their associated high costs present the primary obstacle to the full utilization of small-satellite technology. AFRL and CSA Engineering collaborated under an SBIR contract to develop a standard secondary payload accommodation on the EELV.

Providing Satellites a Smoother Ride to Orbit

Payoff

As a part of the Small Business Innovation Research program, AFRL Space Vehicles Directorate's Soft Ride for Small Satellites vibration isolation team and CSA Engineering, Inc., designed, fabricated, component-tested, whole-spacecraft-tested, delivered flight hardware for, and successfully flew the world's first whole-spacecraft vibration isolation system on Orbital Sciences Corporation's Taurus launch vehicle. The vibration isolation team successfully transitioned whole-spacecraft launch vibration isolation technology, providing a technology breakthrough to the Air Force (AF).

This technology will enhance existing AF capability and greatly reduce costs for current expendable launch vehicles as well as for future expendable and reusable launch vehicles. To date, this system has protected a total of seven satellites spanning six launch missions.

Accomplishment

The team's vibration isolation system was the first whole-spacecraft vibration isolation system flown on a spacecraft. The whole-spacecraft vibration isolation system successfully flew on the Ball Aerospace-built Naval Research Laboratory Geosat Follow-On spacecraft during an orbital mission flown out of Vandenberg Air Force Base, California, to study physical oceanography.

The team is now actively involved in transitioning whole-spacecraft vibration isolation to other missions and users due to the flight demonstration's extreme success. In addition, the National Reconnaissance Organization (NRO) used this system on its Space Technology Experiment (STEX) spacecraft. The isolation system reduced the structural-borne vibrations on the spacecraft by a factor of 3 to 5 while meeting all launch vehicle and spacecraft requirements. The STEX mission manager estimates that this system saved the NRO $20 million in redesign and schedule costs.

The team is currently performing feasibility analysis for the Military Satellite Communications Joint Program Office, which is focused on evolved expandable launch vehicle missions. The technology will be converted into a space asset once it is baselined in the Peacekeeper launch vehicle.

Background

In the last 10 years, billions of dollars have been lost due to satellite malfunctions and failures resulting in mission failure and loss of performance. Reduced vibration environments for future spacecraft will impact the overall cost of spacecraft design, testing, and operation. With suitable vibration environments, several subsystems, like solar arrays and other flexible structures, will become lighter and use less expensive materials, resulting in both a mass and production cost savings.

Space Sensors Developed and Launched for Air Force Weather Agency

Payoff

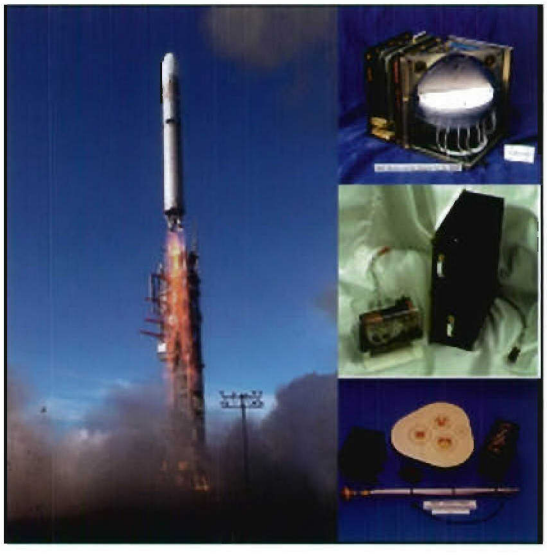
The AFRL Space Vehicles Directorate developed and launched a complement of space environmental sensors to provide critical space weather information to the Air Force Weather Agency (AFWA). The laboratory-developed sensors provide operators with unprecedented environmental monitoring capabilities to better assess the impact of space on defense systems and military operations.

Accomplishment

AFRL launched a complement of new, state-of-the-art space weather sensors on the Defense Meteorological Satellite Program (DMSP) F-16. The new space sensors for DMSP are the ionospheric cold plasma sensor, the auroral electron and ion spectrometer, and the magnetometer.

Background

The Department of Defense (DoD) has an operational need to measure and assess the impact of the terrestrial space environment on military operations conducted within or through space. The space environment affects a broad spectrum of military operations, including navigation, communications, early-warning radar, and satellite operations. The AFWA is the organization responsible for providing accurate, relevant, and timely space weather information to the DoD, national programs, and US coalition partners.



The DMSP is the backbone of the Air Force's global space weather mission to specify the near-earth space environment. DMSP space weather data is used as input to numerous user products generated at AFWA and shipped to the field. For over 25 years, AFRL scientists have provided numerous space environmental sensors to the DMSP's space weather mission. As part of a continuous product improvement effort, these sensors have evolved to take advantage of the latest developments in microelectronics, space processors, and microchannel plate technologies.

Adaptive Beam Control Significantly Improves Airborne Laser Performance

Payoff

The airborne laser (ABL) is envisioned as a theater ballistic missile in the boost phase of flight. The ABL high-energy laser (HEL) must be accurate enough to remain trained on a target moving at approximately 1500 meters per second at a distance of hundreds of kilometers. To satisfy this requirement, AFRL and CSA Engineering developed a beam control system to mitigate jitter due to on-board acoustic and vibration disturbances. This technology significantly enhances the performance of the ABL beam control system, reducing risk and jitter by a factor of two in the HEL subsystem.

Accomplishment

Under a Small Business Innovation Research (SBIR) Phase II contract, directorate engineers and CSA Engineering are developing a novel adaptive filtering and disturbance feedforward (AFDF) technique to mitigate jitter due to aero-acoustic and structural vibration disturbances acting on the ABL turret, laser benches, and stable platform. Based on the results from the SBIR Phase I effort, the AFDF approach was selected for insertion into the ABL program and will be applied to the stable platform in the Block 04 aircraft.

AFDF can be implemented in parallel to an existing control system supplementing the baseline control system, which will not jeopardize the performance. If AFDF is unsuccessful, it can simply be disconnected, allowing the conventional system to function as designed. If AFDF is successful, it will significantly improve line-of-sight pointing.

Background

The environment in which the HEL operates is intense due to aero-acoustic and structural-borne vibration disturbances. The resulting jitter causes performance degradation in the acquisition, tracking, and pointing beam train system. The SBIR Phase I effort focused on evaluating the risk reduction potential of the AFDF approach in this application, as well as developing the simulation tools and design techniques required to design and implement AFDF in the SBIR Phase II. A spatially distributed sensing technique was combined with the AFDF approach to simultaneously control and mitigate vibration/acoustic-induced effects on the coupled aircraft-HEL system.

Near-field Infrared Experiment Track Sensor Payload Delivery

Payoff

AFRL is successfully completing the Missile Defense Agency (MDA)-sponsored near-field infrared experiment (NFIRE) track sensor payload with its Science Applications International Corporation (SAIC) contractor in record time. The highly complex, multiwaveband sensor suite will take only 14 months from contract signing until payload delivery.

Accomplishment

AFRL and SAIC designed, built, fabricated, and tested the complex, multisensor infrared payload with very fast slewing and tracking capabilities. The NFIRE satellite is the MDA's demonstration satellite program aimed at collecting infrared rocket plume data at very close ranges in support of its Kinetic Energy Interceptor program. NFIRE will fly a set of tracking sensors to collect data on boost- and ascent-phase targets of opportunity. NFIRE will also use its sensor to conduct early launch detection of both dedicated strap-down and boosting rocket targets.

Background

Through its SAIC contractor, AFRL provides the track sensor payload used for observations of target plumes and backgrounds. This payload provides acquisition, tracking, and pointing algorithms independent of the NFIRE space vehicle and can track in one sensor while collecting science data in the remaining sensors. The sensors use a common axis telescope and scan mirror assembly to give a very wide and versatile field of regard. Very fast motors and controllers allow the gimbal assembly to track an ascending target vehicle during a possible close-range, fast flyby.

Lightning Protection Developed for Airborne Laser Aircraft

Payoff

A rotary lightning protection system (RLPS) was developed for the Airborne Laser (ABL) aircraft. The technology is a significant advancement over the current state of the art due to its minimal wear and particulate generation, low electrical noise production, and ability to perform well in extreme environments.

Accomplishment

Honeybee Robotics developed an RLPS for the ABL aircraft under a Small Business Innovation Research (SBIR) Phase I contract. AFRL awarded Honeybee an SBIR Phase II contract to further develop the technology for integration with the turret interface of ABL aircraft.

Concept drawing of RLPS for ABL turret

RLPS conductive wheel hardware

The RLPS combines the metal mesh/coating approach to lightning strike mitigation with the innovative rotary band contact technology to provide a ground path for rotating composite structures. The Phase I effort focused on designing and testing the conductive wheels, the flexible rolling elements of the RLPS. Specific attention was given to wheel material selection, providing a large contact surface area between the wheels and the inner and outer races of the ABL turret interface, flexure compliance as it relates to imperfect surfaces and geometries, corrosion resistance, weight reduction, and ease of manufacture and implementation.

The conductive wheels are designed to pass very large currents with negligible wear and particulate generation. The wheels can operate under compression for extended periods of time but will also perform well after long periods of inactivity, as are common during ABL operations.

Background

The Phase II SBIR laboratory-sponsored effort will result in a mature RLPS design for the ABL aircraft. Aside from lightning protection, the RLPS can also be integrated into any system requiring power and/or data transfer across rotating interfaces. With further development during Phase III commercialization activity, the RLPS is expected to provide a more attractive alternative to existing lightning protection and rotary power systems.

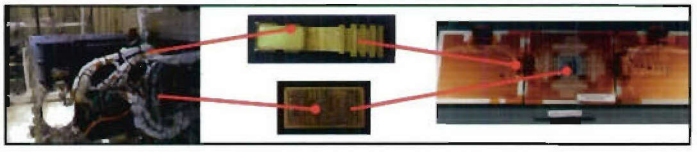
Multifunctional Structures Reduce Aerospace Electronics Size, Weight, and Touch Labor

Payoff

Multifunctional structures (MFS) technology is critical for enabling the aerospace community to develop next-generation satellites, launch vehicles, and missile systems. MFS methodologies dramatically decrease mass and volume for aerospace electronic circuitry and processing units. A study conducted by AFRL and Lockheed Martin concluded that the touch labor associated with avionics buildup, integration, and diagnostic testing can be reduced by more than 50%. This translates to hundreds of thousands of dollars in labor savings on large aerospace systems, such as Lockheed's Atlas V and Boeing's Delta IV expendable launch vehicles (ELV).

Accomplishment

Three space flight demonstrations were conducted, demonstrating the effectiveness of MFS concepts to mitigate technical risk and prepare the technology for operational transition. The first experiment flew on the National Aeronautics and Space Administration's (NASA) Deep Space-1, the second on NASA's Earth Observing-1 satellite, and the third on the United Kingdom Defense Evaluation and Research Agency's Space Technology Research Vehicle-1D. These successful experiments paved the way for various MFS technology transitions that are managed by AFRL.



The Airborne Laser program is incorporating MFS for structurally integral vehicle health monitoring on three different subsystems. The Air Force Global Hawk unmanned air vehicle is retrofitting its splitter box and power discrete controller with an MFS design to save mass and increase reliability. Boeing's Delta IV ELV is retrofitting its avionics deck with flexible circuitry and fully shielded interconnects to save mass and reduce integration and test times.

For circuitry, mass and volume are reduced by approximately 60% and 70%, respectively. This reduction in size allows electronics to be embedded into a composite structure, essentially making it multi-functional. Structurally integral health monitoring and reconfigurable flexible circuit concepts are just two examples of viable MFS applications.

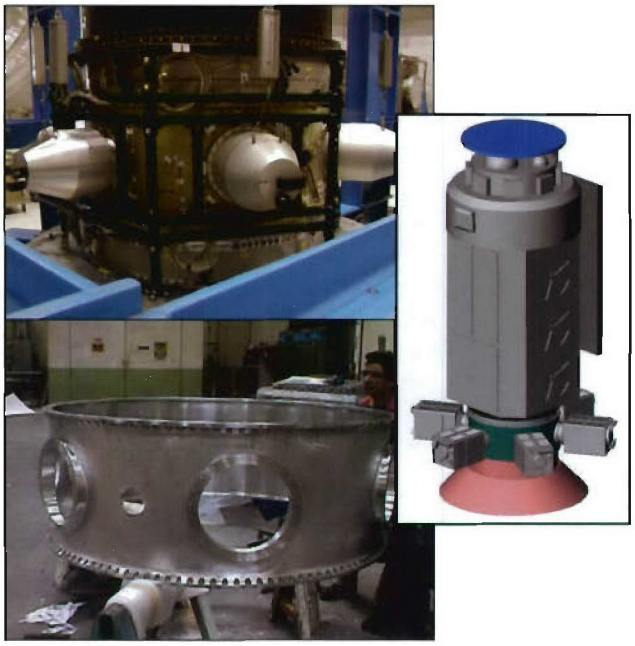
Background

Conventional aerospace vehicle electronic configurations utilize heavy, cumbersome round-wire cabling and canon-plug-type connectors. Aerospace design engineers prefer to utilize these cabling concepts due to their flight-proven heritage, but these designs certainly do not offer an optimized solution for today's complex aerospace weapon systems that require more processing and circuit capabilities and less system mass. During the last 20 years, the development of lightweight flexible circuits, interconnects, and high-density processors enabled the development of many modern commercial electronic devices that include laptops, cell phones, personal data assistants, and so on. AFRL is tailoring these technologies to benefit the aerospace industry.

EELV Secondary Payload Adapter Flight Qualified

Payoff

AFRL's Integrated Structural Systems Team developed and flight-qualified the first secondary payload adapter for the Department of Defense's primary space launch vehicles: Delta IV and Atlas V.



Accomplishment

The team's unique expertise in structural design, analysis, and testing was combined with the vision of the Space and Missile Systems Center's (SMC) Space Test Program Office to develop a secondary payload capability for the Delta IV and Atlas V series of evolved expendable launch vehicles (EELV). The team started with only basic guidance and developed a complete flight-qualified system that will enable constellations of small payloads to launch on a single space launch vehicle, saving as much as $15 million per spacecraft in launch costs.

Background

AFRL led the development of the EELV Secondary Payload Adapter (ESPA), which will enable small secondary spacecrafts to be launched on the Atlas V and Delta IV series of launch vehicles. This program was a cooperative development between AFRL and the SMC Detachment 12 Space Test Program. Funding was also provided through the Small Business Innovation Research program. The ESPA program highlights AFRL's ability to provide innovative solutions to meet warfighter needs rapidly and efficiently.

Emerging Technologies

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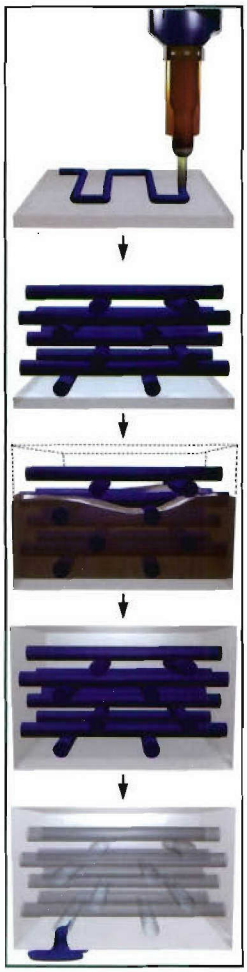
Fabricated Microvascular Networks



Payoff

Support from the AFRL Air Force Office of Scientific Research (AFOSR) and the National Science Foundation may allow a revolutionary change for miniature sensors, chemical reactors, and computers used for everything from biomedicine to information technology. AFRL and a team of scientists discovered a technique for fabricating three-dimensional (3-D) microvascular networks. These networks are highly efficient, space-saving mixers in microfluidic devices and should improve the design of self-healing materials.

Accomplishment

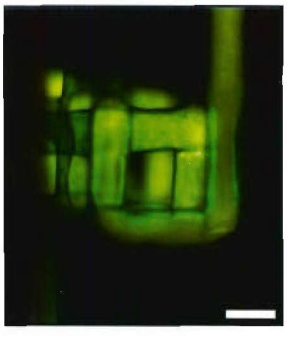
Mr. Scott White, an AFRL AFOSR-funded aeronautical and astronautical professor with the Beckman Institute for Advanced Sciences and Technology, teamed with University of Illinois scientists to discover a technique for fabricating 3-D microvascular networks by using a direct-write assembly of organic ink. These miniscule networks can work as compact fluidic factories in sensors, chemical reactors, and computers.

The team was able to produce a pervasive network of interconnected cylindrical channels that can range from 10 to 300 microns in diameter. The team tested its fabrication technique by building square-spiral mixing towers within the microvascular networks.

Microcapsules of healing agents are distributed throughout the material. When damage occurs locally, the capsules break open and repair the material. Using capillaries to carry the healing agent, the performance of self-healing materials can significantly extend the lifetime of the material.

Background

With the help of a robotic deposition apparatus and a fugitive organic ink, the team created the microvascular network by fabricating a scaffold. Similar to decorating a cake, a computer-controlled robot squeezes ink out of a syringe to build the scaffold layer by layer.



Once a layer is generated, the stage is raised and rotated, and then another layer is deposited. This process is repeated until the desired structure is produced. Once the scaffold is created, it is surrounded with an epoxy resin. After curing, the resin is heated and the liquefied ink is extracted, leaving behind a network of interlocking tubes and channels.

During the final step, the open network is filled with a photocurable resin. The structure is then selectively masked and polymerized with ultraviolet light to plug selected channels. Lastly, the uncured resin is drained, leaving the desired pathways in the completed network.

Revolutionary Plasma Method Improves Decontamination Techniques

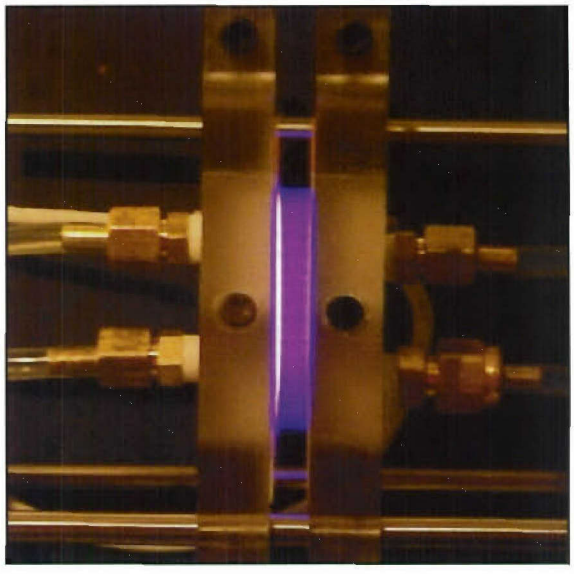
Payoff

Decontaminating equipment or gear exposed to biological warfare agents is an incredibly time-consuming and cumbersome process. However, for those on the front lines and elsewhere, Dr. Mounir Laroussi developed a revolutionary method that uses plasma to speed up that process considerably. Plasma also promises to serve those in the military and civilian medical communities by decontaminating and sterilizing reusable medical tools that are heat sensitive.

Accomplishment

In the 1990s, the AFRL Air Force Office of Scientific Research (AFOSR) began sponsoring Dr. Laroussi's plasma research. Dr. Bob Barker, program manager for AFRL AFOSR's Physics and Electronics Directorate, was visionary in foreseeing the value of the research and its potential use for the Air Force and military. Dr. Laroussi, an Old Dominion University associate professor of electrical and computer engineering, has been looking for a way to improve decontamination techniques for years.

Conventional decontamination techniques rely on extreme heat or chemicals to deal with biohazards and can be time consuming. Plasma is formed when enough energy is added to a gas to free electrons from a significant number of atoms or molecules. This process, known as ionization, creates a mixture of positively charged particles, negatively charged particles, and various uncharged particles. Among these particles are high concentrations of free radicals, which can quickly overwhelm the natural defenses of living organisms, leading to the organism's destruction. This makes plasma a very efficient decontamination agent that can be applied anywhere in a few seconds to minutes.



Hospitals use toxic gases such as ethylene oxide as a method of sterilization. This time-consuming, environmentally unsafe process can require up to 24 hours for the gases and residues to dissipate. In addition, medical professionals working in makeshift hospitals near the battlefield often do not have excess sterilized equipment. Plasma would allow these individuals to reuse their equipment repeatedly, since the tools can be sterilized in just a few minutes.

Background

When Dr. Laroussi's plasma research started in the 1990s, there were few researchers in this area of study. Now this research is common among research groups around the world.

Decontamination is not the only advantage of plasma use. Researchers foresee using plasma in aerodynamic applications to reduce drag, thereby saving fuel. Scientists also discovered that in as little as 10 seconds, high concentrations of bacteria can be killed after exposure to plasma. Other tests have demonstrated that plasma can neutralize microorganisms similar to anthrax and bacteria such as Escherichia coli (commonly referred to as E. coli). Its use also may prove effective in destroying prion, the protein linked to "mad cow disease."

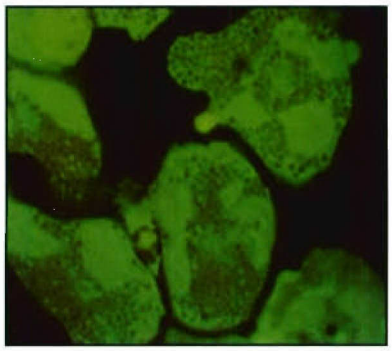
Bioelectrics–Two Worlds Combined

Payoff

What began as a quest to decontaminate water may lead to the link that cures cancer and obesity. Dr. Karl Schoenbach, an electrical engineer, and Dr. Stephen Beebe, a cell biologist, are working together to use pulsed power to kill bad cells in humans. They also discovered military applications using pulsed power for nonlethal force and also to examine the effectiveness of bioelectric techniques for rapid wound healing.

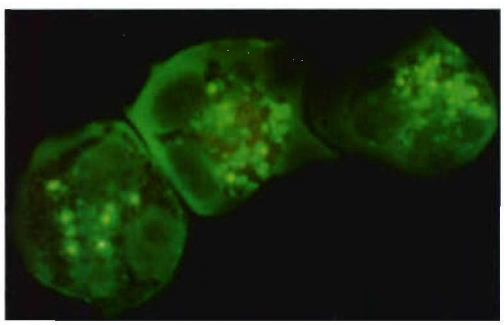
Accomplishment

The AFRL Air Force Office of Scientific Research was the driving force behind the new facilities for Dr. Schoenbach and Dr. Beebe, providing the means to do interdisciplinary research to find results more quickly. They focused their attention on using pulsed power on living human cells. They worked on ways to kill unwanted cells, like tumors and fat cells, and affect cell function.



While making other discoveries along the way, Dr. Schoenbach and Dr. Beebe became the first scientists to show that cancer cells could be coaxed to die by using ultrashort electrical pulses. They learned that if they used pulses below the threshold of killing a cell, they might enhance cell function. This technique has applications in wound healing and expanding stem cells for use in gene replacement therapies. In addition, the number of obese people could be reduced by using pulsed power to kill fat cells, in much the same way cancer cells are killed.

While many marveled at the scientists' breakthroughs, others were pleasantly surprised by the results yielded by the team of professional opposites. Biologists and engineers have very different educations and use almost two different languages. The process of learning to understand the other side can be complicated, time consuming, and at times, very frustrating. Dr. Schoenbach and Dr. Beebe found a synergistic approach to science. They are now focusing on wound healing for people experiencing a slow healing process, such as those with diabetes.



Background

In the early 1990s, Dr. Schoenbach, professor at the College of Engineering and Technology at Old Dominion University in Norfolk, Virginia, was looking for a way to use pulsed power to kill bacteria that contaminated water or air. By generating short pulses with extremely high electrical pulses, Dr. Schoenbach was able to affect the problematic cells.

Dr. Schoenbach, an engineer, began to ponder the effects pulsed power would have on other living cells; therefore, he teamed with Dr. Beebe, an Eastern Virginia Medical School pediatrics professor and a trained biochemist who has worked in molecular and cell biology.

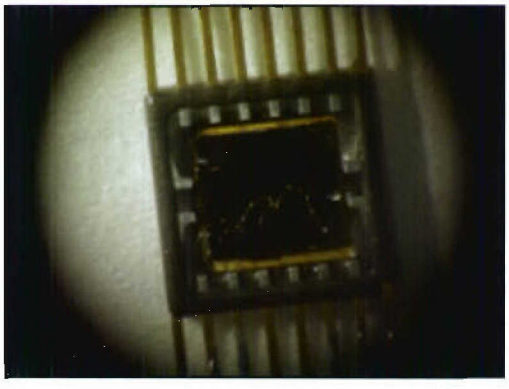
Breakthrough in Nanotechnology Long-Wavelength Infrared Detection

Payoff

The efforts to follow enemy aircraft at night may take a quantum leap thanks to a collaborative research effort and a breakthrough in quantum dot infrared photodetectors (QDIP). Through the Multidisciplinary University Research Initiative (MURI), the AFRL Air Force Office of Scientific Research funded scientists from the University of Southern California and University of Texas at Austin to research QDIPs. The semiconductor quantum dot (QD)-tailored properties could impact nanotechnology-based devices such as lasers, detectors, transistors, and tunneling diodes, to name a few.

Accomplishment

Armed with the grant, Dr. Joe Campbell and Dr. Anupam Madhukar established a major milestone for normal incidence infrared (IR) detectors in the 8- to 12-micron wavelength atmospheric window. Using QDIPs, they demonstrated a performance comparable to established quantum well infrared photodetectors (QWIP). Their findings, which appeared in an issue of *Applied Physics Letters*, establishes the use of QDIPs in applications ranging from night vision to environmental monitoring and medical diagnostics.



Background

Semiconductor QDs are nanoscale volumes of one type of semiconductor material surrounded by another appropriate semiconductor. Together they provide new quantum mechanical behavior for the electrons of the three-dimensionally (3-D) confined material not found in materials with less than 3-D confinement. Through appropriate combination of the two types of materials, semiconductor QDs emerge as the most viable semiconductor nanotechnology for communication and IR detection.

Researchers expect that placing QDIPs in a special configuration, called a resonant cavity, can significantly enhance their detectivity. A resonant cavity is essentially two mirrors bounding the space in which the QDs reside. The mirrors allow the passing IR radiation to bounce back and forth, thus passing many times through the region of the QDs. This, in turn, enhances the probability of the passing radiation to be absorbed by the QDs, enhancing their detection.

The MURI program supports basic science and engineering research of critical importance to national defense. The program is focused on multidisciplinary research efforts that intersect more than one traditional science and engineering discipline. By supporting multidisciplinary teams, it is complementary to other Department of Defense programs supporting university research through single investigator awards.

Solar Cell Uses Proteins to Convert Light into Electricity

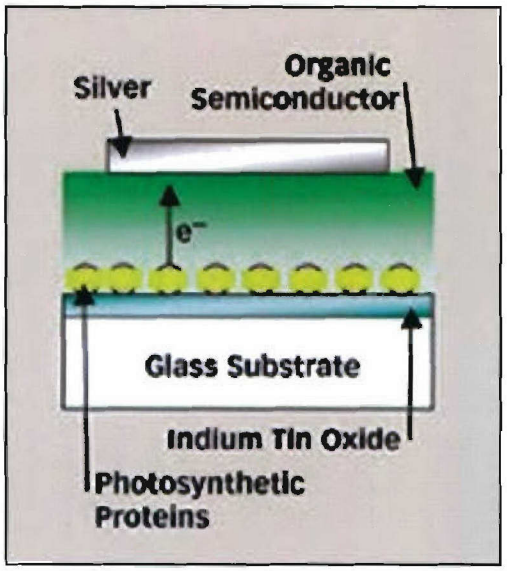
Payoff

Cartoon enthusiasts will tell you that Popeye gained strength by eating spinach. Scientists funded by the Advanced Research and Development Activity through the AFRL Air Force Office of Scientific Research created something even more powerful from such protein-rich sources; they produced electricity.

Accomplishment

Dr. Marc Baldo, an electrical engineering professor at the Massachusetts Institute of Technology, led a team of biologists and engineers who fabricated a solar cell that uses photosynthetic proteins to convert light into electricity. Mindful of efficient ways that plants convert sunlight into sugar, the team created a prototype device that promises a new strategy for making longer-lasting photovoltaic cells.

By using harvested photosynthetic proteins from spinach and the bacterium Rhodobacter sphaeroides, Dr. Baldo and his team were able to make the solar cells. They deposited the proteins onto a glass support and placed a thin layer of the membrane complex on a glass surface coated with indium tin oxide. The team then added a soft layer of an organic semiconductor and topped it with a silver electrode. When researchers shone a light on the device, they observed that the photosynthetic proteins absorbed the photons and shunted excited electrons through the semiconductor layer and into the silver electrode, producing a current.



Background

A protein-based solar cell can be self-repairing, while many solar cell materials degrade over time. Living plants replenish their photosynthetic proteins by swapping the old copies for new ones. Dr. Baldo believes it might become possible to flush a solution of fresh proteins through a solar cell to replace the photosynthetic molecules as they degrade.

Control of Distributed Parameter Systems for Aerodynamic Flows

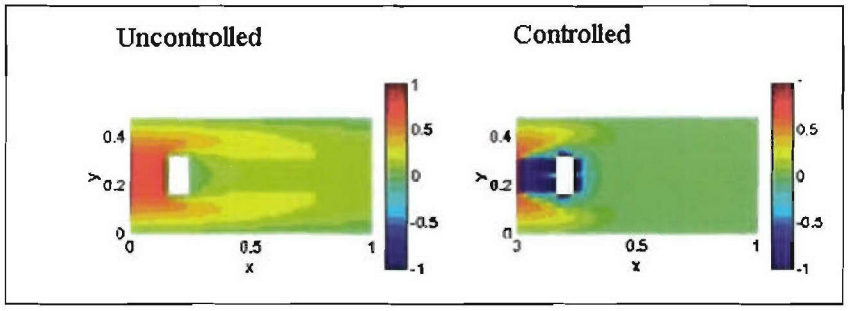
Payoff

Scientists from the AFRL Air Vehicles Directorate have taken the first step in developing a more rigorous methodology for aerodynamic closed-loop flow control. This approach enables more accurate control law designs for various flow control applications, such as drag reduction, lift enhancement, separation control, and virtual aerodynamic shaping.

The approach also facilitates control law development for highly complex systems, including vehicles that maneuver without external moving surfaces. Current methods are incapable of generating accurate and efficient control laws for high-degree-of-freedom systems. This research will lead to more accurate computational analyses across a wider range of operating conditions than currently possible, yielding more robust control laws.

Accomplishment

AFRL researchers successfully completed the first stages of developing a control law for aerodynamic flow control based directly on the fluid dynamics governing equations. This research applies advanced mathematics to computational fluid dynamics in a way never before used in engineering.



Mathematically rigorous feedback control laws for unsteady aerodynamic problems are exceedingly difficult and expensive to calculate with existing methods, because the number of unknowns in the problem is very large. Therefore, methods in the new approach were utilized to greatly reduce the computational cost required to determine the control law, while at the same time maintaining accuracy in the calculations. The first planned application of the technique is flow control near an open cavity like that found in the open weapons bay on a fighter aircraft.

Background

A control law is used to maintain system stability and achieve desired states. Currently, feedback control is applied to flow control on an ad hoc basis. A model developed using both experimental data and data collected from computational fluid dynamics is used to develop control laws.

Data can be collected for only a limited number of conditions, and the resulting control law may be inadequate under conditions for which data was not collected. As a result, situations requiring suppression or enhancement may be missed in the data collection process and, therefore, are not included in the formulation of the control law. The resulting control law would not be as effective as a control law directly created from the partial differential equation.

Validation and Verification of Intelligent and Adaptive Control Systems

Payoff

Scientists at the AFRL Air Vehicles Directorate successfully defined the architectures and characteristics of advanced control systems that may one day control next-generation autonomous air and space vehicle systems. This achievement is the first step in developing validation and verification (V&V) techniques for intelligent and autonomous control. Current V&V techniques are not sufficient to certify intelligent and adaptive control of flight-critical systems.

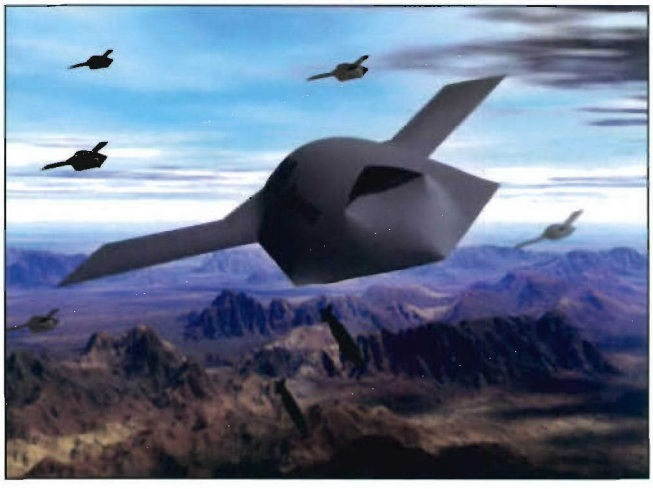
Accomplishment

In the future, V&V of intelligent and adaptive control systems will be used to verify autonomous/intelligent capabilities for air and space vehicle systems. AFRL scientists recently came one step closer to this capability. They defined approximately 100 fundamental properties, as well as V&V challenges, for 10 emerging control systems.

Some of these control systems include automatic air collision avoidance, photonic vehicle management systems, intelligent re-configurable control, and prognostic health management. The control system characteristics defined during this phase will be used to evaluate further investments in research and development.

Background

To safely share airspace with manned aircraft, unmanned air and space vehicle systems must have certain control systems. One of these control systems would give unmanned systems automatic air collision avoidance or "see-and-avoid" capability. Without this capability, unmanned air and space systems are currently segregated from manned airspace, limiting their operational usefulness.



When control systems allow for autonomous interaction, they must be tested to verify their performance. A system must be in place to accomplish this testing prior to flight tests in a real-world environment, where personnel and valuable assets are potentially at risk. AFRL and Lockheed Martin are working diligently to accomplish this difficult task.

AFRL scientists defined the critical architectures and characteristics for these advanced control systems and are developing methods to verify that the control software's autonomous decision making will respond correctly to real-world situations. This next step will be a real-time, hardware-in-the-loop simulation. Successful completion of this final phase will help to ensure the safe incorporation of unmanned air and space systems into actual operational environments.

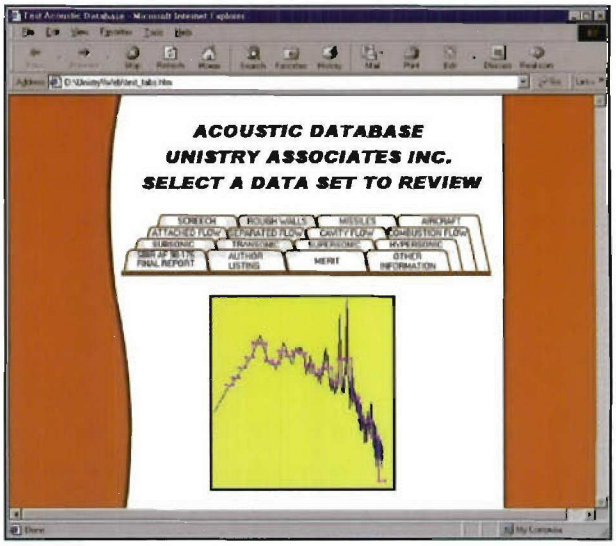
Characterizing Aeroacoustic Loads

Payoff

The AFRL Air Vehicles Directorate developed an accessible and extensive database of dynamic acoustic loads that affect aircraft structure and subsystems. This database will allow engineers to produce aircraft with longer structural life, lower maintenance costs, and increased readiness.

Accomplishment

As part of a Small Business Innovation Research program, AFRL worked with UNISTRY Associates, Inc., to develop a new engineering technique that predicts the loads placed on an aircraft during flight by fluctuations in high-frequency sound pressure. The technique takes data from a variety of sources and compiles it onto one curve. This data makes it easier for engineers to compare and use the information to make better design-performance predictions.



AFRL used this new technique to generate a database that demonstrates how sound pressure varies with changes in frequency for various structural configurations, airflow conditions, and data processing methods. Data on weapons bays and noise generated on pulse-detonated engines makes the database particularly valuable. Currently, the database is available to scientists on a CD-ROM; however, AFRL has developed a commercialization plan to place the database on the Internet.

Background

During flight, an aircraft is subjected to strong pressure fluctuations caused by airflow and acoustic resonance. The resulting acoustic loads have high sound pressure levels at high frequencies that can damage weapons, crack nearby surfaces and components, and radiate intense noise. With the laboratory-developed database, engineers can assess the effects of this phenomenon and use the knowledge to design aircraft with increased structural life, lower maintenance costs, and increased readiness.

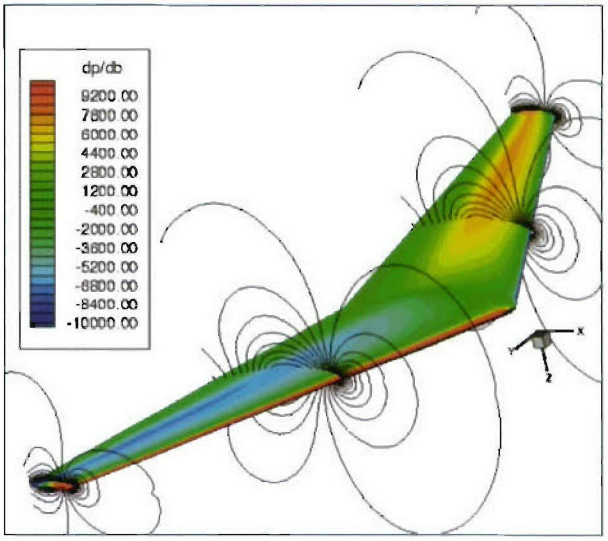
AFRL Improves CFD Analysis Methods

Payoff

AFRL and Aerosoft, Inc., developed a post-processing tool that gives engineers a better way of analyzing solutions obtained using computational fluid dynamics (CFD). This new analysis method provides a greater understanding of CFD results at a fraction of the cost of traditional methods.

Accomplishment

As part of the Small Business Innovation Research program, the AFRL Air Vehicles Directorate worked with Aerosoft, Inc., to improve methods of analyzing CFD solutions. Their efforts led to the development of the Sensitivity Equation (SENSE) software package, which shows how changing a system parameter affects an existing CFD solution. Engineers can use this capability in a number of ways to gain valuable insight into CFD results. For example, instead of the traditional computation of multiple CFD solutions for each design parameter, SENSE can perform parametric studies from a single CFD solution for less than 10% of the cost of traditional methods.



SENSE quickly determines the influence and relative importance of all design parameters to find important trends while significantly reducing vehicle design costs and turnaround time. It can also calculate performance measures such as lift curve slope, and stability derivatives such as roll damping. Since any system parameter can be used, SENSE is also capable of solving other engineering problems. It is a powerful tool and should prove to be a valuable asset in the years to come.

Background

Engineers routinely use CFD to predict the aerodynamic forces and movements of an air or space vehicle at a given flight condition. However, the overall design process requires knowledge of how these forces and movements vary with the vehicle's motion. While CFD can accurately estimate this information, the process has traditionally required solving complicated nonlinear equations. In addition, its high cost has limited its application to large-scale problems.

The sensitivity equation method (SEM) is much more efficient at performing these calculations. It finds solutions to complicated CFD nonlinear equations by using linearized equations, which are much easier to solve. The SENSE software package uses the SEM approach to compute flow field sensitivities. The software is compatible with most CFD flow solvers.

Integrated Adaptive Guidance and Control Technology Testing Successful

Payoff

AFRL developed a reusable launch vehicle (RLV) automatic landing system that identifies and compensates for a variety of in-flight control surface failures. Its use will increase RLV system safety and reliability.

Accomplishment

AFRL Air Vehicles Directorate engineers, in conjunction with Barron Associates, Boeing, and General Dynamics, completed 3 months of flight testing on an automatic landing system that compensates for control system failures in RLVs like the X-40A space maneuvering vehicle (SMV). AFRL researchers and contractors jointly developed the integrated adaptive guidance and control (IAG&C) technology used in the autonomous landing system. During testing, the Total In-Flight Simulator (TIFS) replicated X-40A flight characteristics for 64 evaluations covering approximately 20 different failure situations. Engineers evaluated the IAG&C ability to compensate for single or multiple failures including various combinations of locked control surfaces.

In most evaluations, TIFS "landed" on virtual runways that were actually located 20 to 1,000 ft aboveground. However, during four tests, TIFS made exceptionally smooth landings on an actual runway. Overall, IAG&C successfully handled a significant number of failure scenarios.

Background

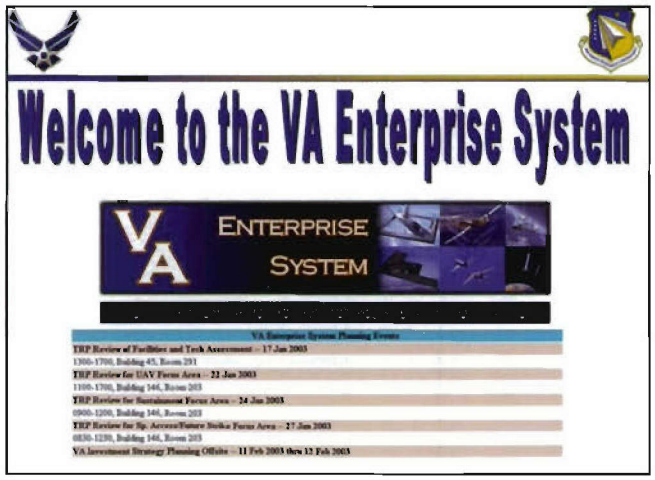
Replacing conventional space access vehicles with unmanned RLVs will greatly reduce the cost of entering earth's orbit. Before RLVs can be widely used, they will need to be safer and more reliable. To achieve this goal, future RLVs will use autonomous control systems like IAG&C to respond the way a human pilot would to failures, damage, or changing conditions.

TIFS is a Convair NC-131H aircraft with a research cockpit grafted onto its nose. Onboard computers run simulation models that give the Convair handling characteristics of the aircraft being tested (the X-40A). The X-40A is a small version of the X-37 SMV prototype, the current candidate for the first SMV platform. The X-40A is a less-expensive, lower-risk way to test X-37 concepts.

VAES Improves Directorate Reporting

Payoff

The AFRL Air Vehicles Directorate developed and implemented the Air Vehicles Enterprise System (VAES) to facilitate management of its corporate processes. This system provides tools for performing configuration management, generating dynamic roadmaps, and conducting laboratory management reviews (LMRs). Additionally, VAES provides a two-level program/project structure, a job order number coding system, and Defense Technology Information Center (DTIC) reporting, saving valuable man-hours.



Accomplishment

VAES configuration management tracks and records all program changes and ensures accurate current-year total obligation authority. AFRL's financial team uses the tool to ensure funds are not overcommitted. The dynamic roadmap capability helps ensure that AFRL stays on the critical path to warfighter needs.

VAES has been used to brief stakeholders on over 200 programs, graphically displayed on seven major roadmaps. Automating LMRs eliminates paperwork, decreases the engineer's workload, standardizes the review format, and provides a historical record. VAES reporting to DTIC eliminated the need for the predecessor system, A Science and Technology Action Report System (ASTARS). Using VAES for DTIC reporting dramatically increases AFRL's reporting accuracy, which reduces Department of Defense-wide research effort duplication.

Background

Previously, program managers used ASTARS to capture program/project information for DTIC. VAES now provides that reporting as well as collecting and managing data to facilitate corporate processes such as lab management reviews, investment strategy, and strategic planning. Currently, AFRL is developing a new set of tools to fully integrate its business processes. These processes are being designed to establish common business practices, data definitions, and tools across the laboratory.

In the interim, AFRL has employed VAES to collect and manage all corporate data such as program technology and funding. VAES use is increasing data accuracy and reporting efficiency. Despite excellent results, AFRL is constantly seeking ways to improve VAES. A user group is also assisting with improving the existing processes and identifying future VAES additions.

AFRL Validates Integrated Thermal Structures Program Research on B-2

Payoff

AFRL combined validation of its current research on integrated thermal structures with research on the B-2 Spirit stealth bomber. As a result, AFRL acquired necessary data while saving the Air Force (AF) millions of dollars.

Accomplishment

Under its Integrated Thermal Structures program, the AFRL Air Vehicles Directorate is creating computer models that predict how structures perform under excessive heat, stress, and acoustic excitation. Engineers typically use generic test articles to validate model accuracy. However, when the B-2 System Program Office requested assistance with B-2 aft deck cracking, AFRL seized the opportunity to acquire validation data while solving a high-priority AF problem.

During tests, scientists successfully validated model predictions regarding the effects of elevated temperature on the B-2 aft deck structure. By using a B-2 ground test airframe that was being restored for public display at the Air Force Museum, they saved the AF the expense of hiring a contractor to conduct tests on the only other such B-2 ground test airframe, located in California. AFRL scientists are also generating models of the full aft deck assembly to support a full life assessment of the aft deck. They will validate these models in the AFRL Consolidated Aerospace Structures Research Facility. Scientists will use data collected from this testing and future testing on an operational B-2 to further refine the models and make recommendations for preventing future aft deck cracking.

Background

Currently, many structures are tested using a trial-and-error method. However, this technique is no longer practical because of the great expense of new thermal-resistant materials. The computer models developed at AFRL will not replace the need to test materials, but they will limit the amount of testing required, by eliminating ahead of time those options destined to fail. Eventually, this technology will be employed on future platforms like that of the space operational vehicle, an unmanned reusable space platform.

B-2 aft deck structural cracking is not a flight safety concern but requires extra maintenance time and expensive repairs. Unlike other airplanes, the B-2's engines are inside its wings. Engine exhaust travels over the aft deck, subjecting it to high temperatures. This, in turn, accelerates structural fatigue and cracking. Original B-2 development models considered the effects of this engine placement, but the computational resources employed at that time were not equal to those available today.

Discrete Roughness Element Testing

Payoff

AFRL Air Vehicles Directorate scientists partnered with Lockheed Martin and Arizona State University (ASU) to investigate discrete roughness element (DRE) technology for maintaining laminar airflow on swept wings. By reducing airfoil drag, DREs could cut down on fuel consumption and increase range or time on station for future aircraft. One day, DREs may enhance the SensorCraft concept's capability to perform persistent intelligence, surveillance, and reconnaissance.

Accomplishment

The team conducted both low- and high-speed wind tunnel testing on a representative airfoil designed for one of Lockheed Martin's SensorCraft concepts. During the low-speed tests at ASU's unsteady wind tunnel, scientists perfected their diagnostic methods, ensured that the model accurately produced the predicted airfoil characteristics, and established requirements for DRE height and spacing. After these preparations, the team moved to the Illinois Institute of Technology National Diagnostic Facility. There, they subjected the model to flow conditions representative of its flight environment. Scientists demonstrated that placing properly sized and spaced DREs on an airfoil increased the oxygen of laminar airflow over that airfoil.

Background

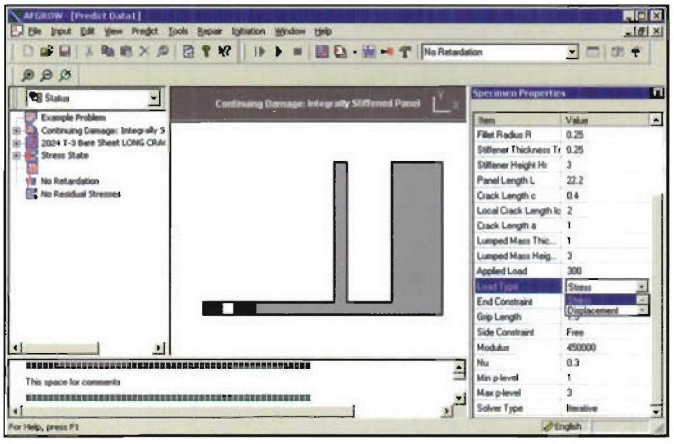
SensorCraft is an unmanned air vehicle concept for intelligence collection. It will be designed around its mission requirements with fully integrated sensors. For example, its wing may double as an antenna.

Initially, when air encounters an aircraft wing, its flow is laminar; that is, it flows in smooth parallel paths called laminas. However, as the air travels over the wing, it experiences friction. This friction slows the lamina nearest the wing and causes instability in the surrounding laminas. The laminas violently mix with one another to create turbulent flow, which increases wing skin friction and increases drag. DREs are small, bump-like structures designed to control the instabilities and inhibit this transition from laminar to turbulent flow, thus reducing drag.

AFRL Improves Crack-Life Prediction Software

Payoff

The AFRL Air Vehicles Directorate has improved the state of the art in structural crack growth prediction. Scientists can now more effectively predict structural crack growth over time. As a result, they can better determine the service life of aircraft structures and set up a preventative maintenance schedule. In addition, they can use this information during the design process to build structures that are more resistant to structural cracking.



Accomplishment

The laboratory-developed external stress intensity solver program links its Air Force Growth (AFGROW) structural crack growth life prediction program with StressCheck®, an industry-wide structural analysis program that can calculate stress intensity factors for three-dimensional (3-D) objects. Scientists demonstrated the external stress intensity solver's effectiveness by calculating crack formation over time from the internal edge of a notch, i.e., a rounded indentation on the outside edge of a surface. In the future, AFRL scientists aim to build upon this new capability to determine stress-crack formation for more complex structures.

Background

When using AFGROW in the past, scientists needed to make assumptions about how a structure's 3-D quality would affect the stresses near the crack tip that lead to crack formation. However, StressCheck can now feed AFGROW this information during the computational process, eliminating the need to make assumptions and increasing AFGROW's accuracy.

AFRL has been continually developing and improving AFGROW for over a decade. Many members of the aerospace industry use AFGROW, but it can be applied to any structure that experiences fatigue cracking. AFGROW is available to everyone online and free of charge.

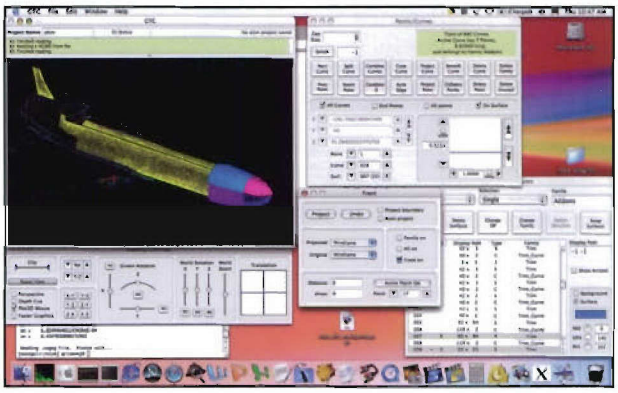
AFRL/NASA Team Releases Award-Winning Software

Payoff

The AFRL Air Vehicles Directorate created an interface that allows the National Aeronautics and Space Administration (NASA) Tetrahedral Unstructured Software System (TetrUSS) software to work in the Apple Mac OS X operating system. Now, scientists can use a Macintosh personal computer to perform computational fluid dynamics (CFD) calculations that previously required an expensive workstation. Not only does the development reduce operating costs, but it also makes the TetrUSS software available to any organization with commodity personal computers.

Accomplishment

As a part of an interagency agreement with NASA, AFRL ported components of NASA's TetrUSS 2004 software to Apple's Macintosh computers. The new development allows scientists to use a personal computer to perform the same calculations that previously required an SGI workstation.



Since NASA released TetrUSS 2004, the software has won two significant awards. First, the software earned the 2004 Apple Computer Design Award for the best Mac OS X scientific computing solution. For this award, Apple presented the team with a state-of-the-art Macintosh computer, which will remain at AFRL, and a trophy, which will be displayed at NASA. Second, TetrUSS 2004 was cowinner of NASA's Software of the Year Award.

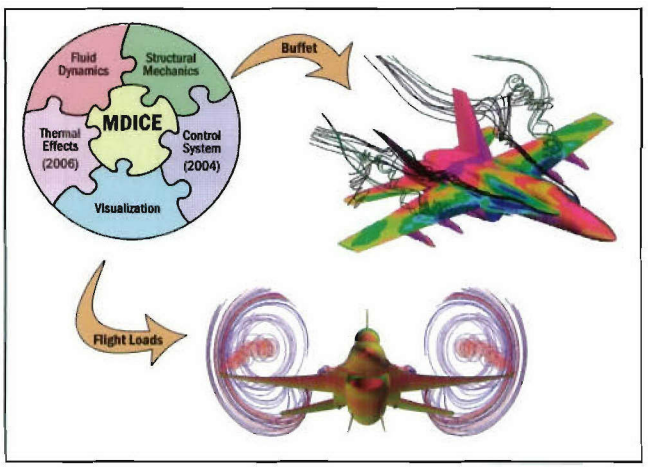
Background

More than 500 organizations throughout the nation use TetrUSS software, including government; academia; and the aerospace, automotive, bio-medical, and civil engineering industries. TetrUSS 2004 is a group of computer programs used for CFD (i.e., using computers to find solutions to fluid flow problems, such as the study of air flowing over an air vehicle's body).

Computational Framework Simplifies Multidisciplinary Analyses

Payoff

The Multidisciplinary Computing Environment (MDICE) is a flexible software application that enables communication between incompatible engineering software applications to solve complex multidisciplinary problems. MDICE increases efficiency and allows integration of engineering tools without the time and expense of modifying existing, proven, user-friendly computer programs. MDICE makes possible those computer models that were previously too complex, but which are necessary to develop the air and space access vehicles of the future.



Accomplishment

AFRL partnered with CFD Research Corporation and the Lockheed Martin Aeronautics Company to further develop MDICE, which facilitates solutions to multidisciplinary, physics-based computer models. MDICE allows integration of computer programs from different technical disciplines with many different formats. For example, MDICE can simultaneously integrate computer graphics, computational fluid dynamics codes, and structural analysis programs. Without MDICE, these computer programs are incompatible, but with MDICE, they can exchange information and work together to solve complex problems.

Background

In the past, aeroelastic problems, which combine aerodynamic, inertial, and elastic forces, used relatively simple linear models. These models made the problems easy to manage, but their simplicity resulted in a lack of accuracy. Developing future air and space access platforms required a higher level of accuracy, but this accuracy was unobtainable without a program to link established engineering tools in a consistent and accurate manner. MDICE provides this link.

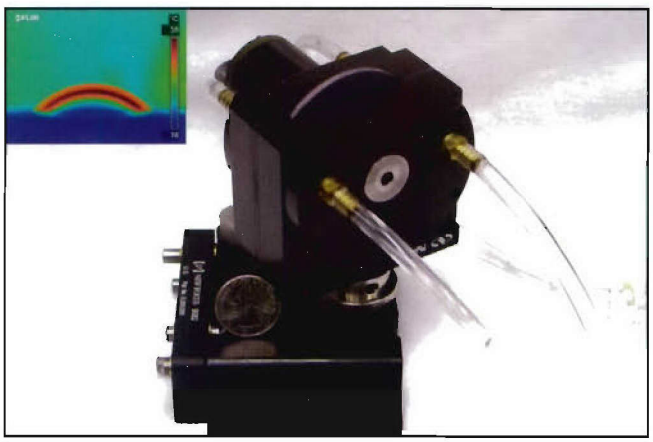
Spinning Disks Show Promise for High-Power Laser Designs

Payoff

Scientists from AFRL's Directed Energy Directorate demonstrated a spinning disk glass laser at an unprecedented 35-watt (W) continuous wave output power to demonstrate the excellent thermal characteristics and power scaling potential of spinning disk laser architectures. By spinning a large disk of gain material in a laser cavity, waste heat is spread throughout the entire disk. This technique dramatically increases the thermal damage threshold of the solid laser material while reducing thermally induced beam distortions, and may allow scaling to tactically significant power levels.

Accomplishment

AFRL scientists procured an apparatus to precisely rotate and cool disks of solid gain material and designed a laser system around this apparatus that produces high-quality (diffraction limited) continuous power from glass. As a laser gain material, glass can be manufactured in arbitrarily large pieces, but it is known for its poor thermal characteristics under continuous (100% duty cycle) operation. It is highly susceptible to thermal fracture and exhibits a high degree of thermal distortion. Spinning disk lasers require large disks of material to generate high powers, and the results of the new laser using a small glass disk demonstrated the technique's scaling potential.



Using 115 W of diode-laser pump power, scientists pumped a 3.3% Nd:glass disk, 60 mm in diameter and 3 mm thick, to achieve 35 W of output power—20 times the previous spinning disk power record. The power output is optimized at rotation speeds of 300–400 rpm. Cold metal plates spaced 50 mm from the faces of the disk actively cool the laser gain material, allowing heat to conduct across the air gap.

Separate experiments using a 1.1% Nd:yttrium aluminum garnet (crystal) disk generated over 10 W, diffraction limited, with 59% slope efficiency (theoretical maximum is 71%). AFRL scientists expect over 50 W of output power from the crystal disk when it is pumped at 115 W, with the additional power due to the crystal's higher gain and thermal conductivity when compared to glass. Other future efforts include experiments using higher-power pumps, multiple disks in series, larger glass disks, and transparent ceramic gain materials.

Background

Throughout the military services, interest in developing high-power lasers for tactical missions continues to grow. Due to their small size, all-electric operation, and low life-cycle costs, solid-state lasers are an enabling technology for many of the envisioned scenarios. However, thermal problems continue to be an issue for operating solid-state lasers at very high powers.

Spinning disk laser architectures can be used to control the effects of thermal loading in solid-state laser gain media by spreading the waste heat over a large volume of actively cooled material, and the technique allows for efficient end-pumping by laser diodes. In principle, very high output powers can be obtained prior to reaching the thermal limits of the gain medium. With the advent of precision mechanical devices for disk rotation and deformable optics for correcting any residual beam steering, the spinning disk represents a revolutionary scaling path for high-energy, solid-state lasers.

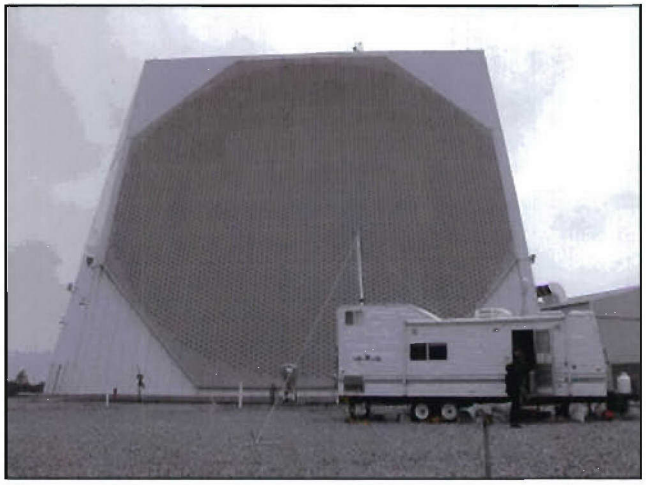
AFRL Measures the Time Domain Signature of the PAVE PAWS Radar

Payoff

AFRL Directed Energy Directorate scientists and engineers successfully completed an extensive series of measurements on the radio frequency output of the missile early-warning system known as the PAVE Phased-Array Warning System (PAWS) radar site located at Cape Cod Air Force Station, Massachusetts. The waveform data was submitted to the National Academies of Sciences to be used to deduce potential biological and health effects from the PAVE PAWS radar. The team's dedication and technical expertise provided the Air Force Space Command (AFSPC) with accurate and technically defendable information to evaluate the performance and safety of the PAVE PAWS radar. It also enhanced public confidence in the United States Air Force.

Accomplishment

AFRL's measurement team successfully acquired accurate time domain measurements of the PAVE PAWS radar in the vicinity of the radar and at selected sites in the surrounding civilian community. Within 9 days, the measurement team collected approximately 700 measurements, including extra measurements that will allow Air Force (AF) personnel to better understand the radar's performance.



The tests determined the instantaneous radar bandwidth and recorded the history of the waveform emitted by the huge phased-array antenna system during one of its pulses. Measurements were taken from the main beam of the radar antenna and at selected sites in the surrounding community. This is the first time a complete chronology of a PAVE PAWS radar pulse has been measured.

Background

The Massachusetts Congressional Delegation, reacting to concerns raised by citizens in the Cape Cod area that the PAVE PAWS radar is a potential health hazard, requested the AF provide detailed information on the emissions from the radar site. AFSPC and the Secretary of the Air Force for Acquisition tasked AFRL's Wideband Technology Team from the High-Power Microwave Division at Kirtland Air Force Base, New Mexico, to measure the time domain radio frequency signature emitted by the PAVE PAWS radar system at the Cape Cod station.

The AF assembled a group of scientists and engineers from across the country to plan the measurement program. The resulting plan called for an iterative process across four phases. Phase I provided a preliminary characterization using a numerical model to guide the measurement effort. Phases II and III measured a single element and two elements of the radar and determined the radio frequency energy spectrum background in the communities surrounding the radar. Phase IV performed a waveform characterization of the entire radar system.

Breakthrough Achievement of Positive Gain in the Electricoil Laboratory System

Payoff

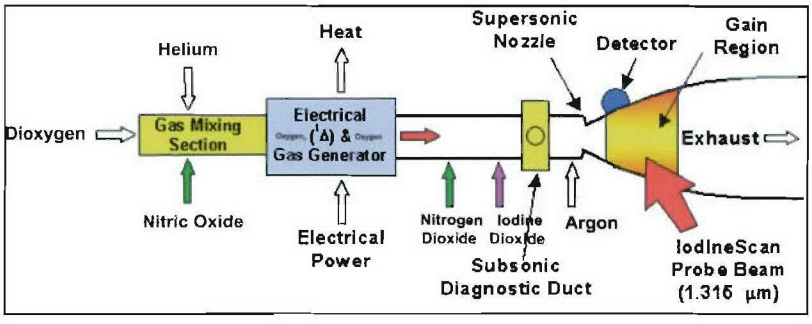
Work sponsored by the AFRL Directed Energy Directorate and the Missile Defense Agency led to the first observations of gain in a continuously flowing electric discharge-driven, oxygen-iodine laser system. An electrically pumped, all-gas-phase, oxygen-iodine laser system would be a highly desirable successor to the chemical oxygen-iodine laser (COIL) system that is currently being developed for the Air Force's airborne laser system. When developed, such a laser could be operated continuously with onboard power, minimizing logistics trails required for fielded systems.

Accomplishment

Work led by scientists and engineers at the University of Illinois at Urbana-Champaign (UIUC) and CU Aerospace demonstrated an all-gas-phase laboratory system with positive gain on the 1315 nm electronic transition of atomic iodine. ElectriCOIL, an advanced chemical iodine laser concept, consists of several basic elements.

First, the excited oxygen donor for the iodine atom, $O_2(^1\Delta)$, is created in the laboratory by an electric discharge. In this case, a radio frequency discharge generator applied to a high-speed gas phase flow of ground state oxygen was used to create the electronically excited oxygen energy carrier molecule. Second, an iodine flow system injects molecular or atomic iodine into the laser cavity region for lasing. Finally, a laser resonator is coupled to the supersonic flow to facilitate laser oscillation and energy extraction.

This result represents the first laboratory demonstration of positive gain for a COIL device where the $O_2(^1\Delta)$ energy carrier is generated by an electric discharge. The principle advantage of such an approach is the replacement of the massive fluid supply/tankage subsystem by a small, fixed-mass electrical subsystem for the generation of excited oxygen.



Background

Steady improvements to the discharge flow and stability, along with significantly enlarged theoretical and experimental databases, have led to a more complete understanding and attainment of positive gain. A team from the Air Force Institute of Technology, CU Aerospace, Emory University, Physical Sciences, Inc., and UIUC are addressing unresolved questions related to processes occurring in this electrically driven oxygen-iodine laser system.

The team is conducting a Joint Technology Office-funded multidisciplinary research program under the direction of AFRL. This program places emphasis on basic university research and targets the evolving ElectriCOIL technology, the ultimate development of ElectriCOIL systems, and the education of future scientists and engineers.

Air Force Medics Improve Navigation Time With 3-D Audio

Payoff

Technology that delivers quick, effective positional information about an injured or missing person will help save time and lives. When combined with positional data for team members and targets, three-dimensional (3-D) audio displays provide an alternative to visual displays with positional situational awareness when eyes and hands are task loaded.

Accomplishment

Testing of the 3-D audio prototype began with a subject panel in the AFRL Human Effectiveness Directorate located at Wright-Patterson Air Force Base, Ohio. Additional tests were conducted with Air Force (AF) medics in a semioperational environment field exercise.

During the AF medics' annual field training, the 3-D audio navigation cueing interface resulted in a dramatic reduction in navigation time when compared to the traditional navigation methodology featuring maps, compasses, and step counting. The 3-D audio symbology uses headphones, head tracking, a Global Positioning System, and digital audio processing to simulate externalized range through voice-based distance cueing and bearing cueing. Post-experiment survey results indicated an overwhelming preference and desire for fielding the 3-D audio cueing technology.

Background

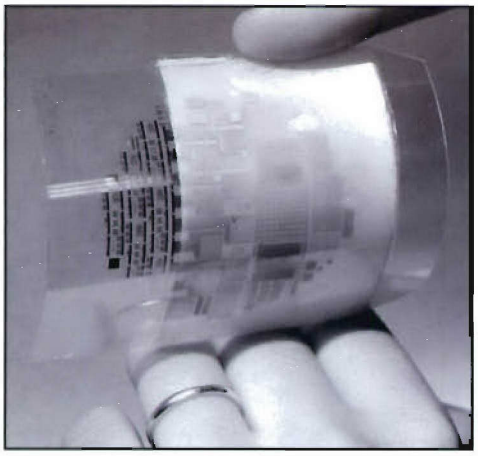
Two units of AF medics performed land navigation tasks during a daylight field exercise in fully wooded conditions. The laboratory-developed 3-D audio system, was measured against the medics' current land navigation procedure (map, compass, and step counting). The dependent variable during the field exercise was the time it took the medics to cross to a waypoint—the place between major points on a route. Results showed a dramatic decrease in navigation time with the 3-D audio cueing technology compared to the current land navigation system.

Full demonstrations of the technology were also held at the annual Phoenix Warrior exercise. According to a Phoenix Warrior trip report, users were able to navigate strictly by audio both day and night after a short training period. The technology also allowed users to put their heads down and focus on foot placement and terrain, thereby enhancing user safety.

AFRL Improves Reliability of Thin Display Screens

Payoff

Flat-panel displays with thin display screens are used in portable computers, incorporate all sorts of technologies, and are found in numerous environments; however, these displays are not flexible. The AFRL Human Effectiveness Directorate is improving the reliability of these displays by making them flexible. Flexible displays will be more suitable in turbulent conditions because they can be used without jeopardizing their functionality. The flexibility would benefit electronic maps, dual-use applications, maintenance crews on the flight line, pilots who use kneepad and wrist displays, and the use of displays under adverse conditions like shock and distortion.



Accomplishment

A flexible thin film transistor (TFT) is a requirement for high-quality, high-resolution flexible displays. Working with a team headed by two major universities, AFRL conducted in-house testing of a flexible TFT substrate with sustained performance. By improving the reliability of a flexible TFT substrate, AFRL is improving the overall reliability of high-resolution flexible displays. Their work also provides a much-needed link to the Air Force, display industry, and research and development communities for leveraging the technology.

Background

Since the introduction of flat-panel displays, continuous effort has been made to enhance the display quality. Very little work has been done on the development of flexible TFT drivers. As such, flexible TFT drivers have been the weak link in the system of flexible displays.

The intent of this particular effort, part of the Enabling Technology for Thin Film Displays program, was not only to develop a flexible display but also to enhance the overall quality of a flexible display. AFRL exerted a concerted effort to improve the quality of flexible TFT drivers by using plastic and metallic substrates so that high-resolution flexible displays become feasible and more reliable. To meet those goals, AFRL engineers developed a high-performance polysilicon TFT on plastic by both direct deposition and separation/application-onto-plastic technologies.

Integrated Assessment of the Spatial and Temporal Resolution of Flight Simulator Displays

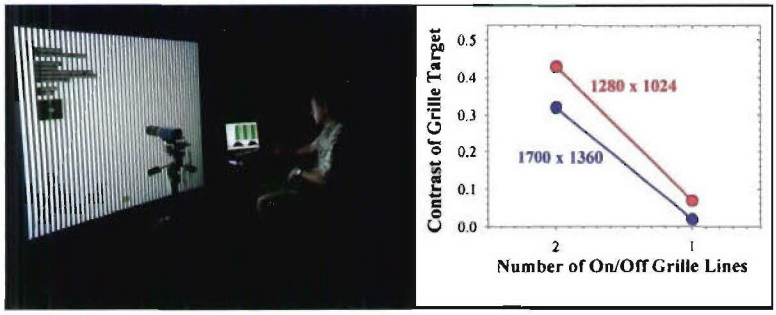
Payoff

The AFRL Human Effectiveness Directorate has developed techniques to quickly and accurately measure the spatial and temporal resolution of flight simulator visual displays. Spatial and temporal resolutions are fundamental and critical characteristics of the flight simulator displays used to train Air Force pilots for a multitude of missions. Accurate assessment of display resolution is used to assess the efficacy and limitations of flight simulators in pilot training. These techniques have been used in the procurement of current flight simulator display systems and in the development of next-generation, high-resolution projectors.

Accomplishment

AFRL verified that the measured spatial resolution does not correlate well with the number of displayed pixels, which is the measure typically cited by display manufacturers and users. The spatial resolution measure correlates well with performance on aircraft discrimination tasks requiring high image detail. The temporal resolution techniques were used to verify that current projector systems are sufficient to display visual imagery at the update rates available from current image generators.

These techniques have also been used to assess the potential trade-offs of using projectors with high spatial resolution but lower temporal resolution, as well as to make recommendations to projector manufacturers concerning improving the temporal response of their projectors. Experiments performed to evaluate AFRL's resolution measurement techniques were presented at the annual meetings of the American Psychological Association (2000) and the Association for Research in Vision and Ophthalmology (2001), published in *AFRL Technology Horizons®* (2003), and described in detail in an AFRL technical report (AFRL-HE-AZ-TR-2004-0078).



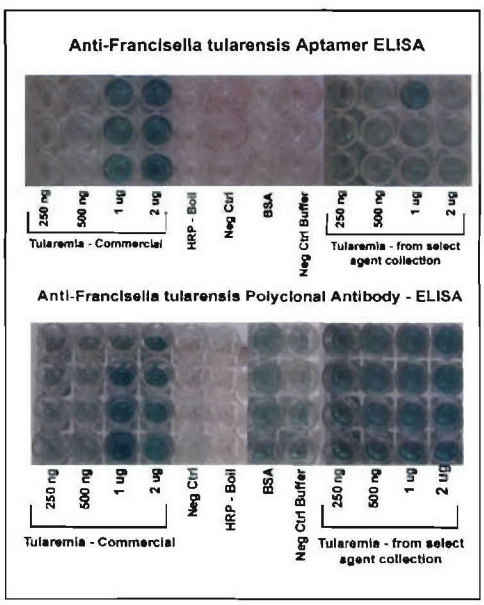
Background

Display manufacturers and users have been somewhat reluctant to adopt the spatial resolution measure most relevant to flight simulator applications. AFRL's relatively simple and intuitive technique to measure spatial resolution will address this problem. Similarly, the techniques AFRL developed to measure temporal resolution were designed for use with current flight simulators whose projector systems can display imagery faster than can be produced by the image generator. Resolution measurement techniques can be used to compare display systems, but they cannot determine what level of resolution is required. AFRL also developed techniques to compare measured resolution with data obtained using visual discrimination tasks typically performed on flight simulators.

Molecules for Biowarfare Agent Detection

Payoff

Deoxyribonucleic acid (DNA) "capture elements," also known as aptamers, are versatile molecules that can be selected to detect biological threat agents harmful to human beings. The most widely publicized examples of such agents include biowarfare threats such as anthrax, tularemia, smallpox, and Shiga toxin. The AFRL research team proved that aptamers are better indicators than antibodies, as aptamers show no incidence of false-positive results and are more specific. AFRL's results also indicate that aptamers can be used to detect biological warfare agents with high specificity and sensitivity.



Accomplishment

AFRL researchers tested aptamers selected against tularemia bacteria to evaluate their ability to detect tularemia bacteria, and they successfully demonstrated that a better signal could be produced upon binding as compared to the signal produced by antitularemia antibodies. The aptamers could differentiate tularemia from other proteins such as bovine serum albumin (BSA) or ovalbumin, whereas antibodies showed some nonspecific signals.

For the tests, AFRL developed a sandwich aptamer-linked immunosorbent assay format for detection. Microtiter plate wells were coated with capture aptamer cocktail. Either tularemia bacteria, BSA, or ovalbumin were incubated with the capture aptamer. The presence of bacteria was detected with a reporter aptamer conjugated to biotin, which in turn binds streptavdin-linked alkaline phosphatase to create a visual/color signal. Only those wells incubated with bacteria showed the color signal. For BSA or ovalbumin, very little or no color was observed, indicating that aptamers bound only to bacteria.

AFRL's results were compared to a commercially available antitularemia polyclonal antibody conjugated to alkaline phosphatase. The antibody produced a signal with tularemia, but it also showed some nonspecific binding with BSA and ovalbumin.

Background

Prior to the introduction of aptamers, antibodies were used for the same type of detection, but with many difficulties. The Chemical and Biological Defense Joint Program Office funded this research. The original request was to demonstrate that aptamers were at least as good as antibodies, but AFRL proved they were better.

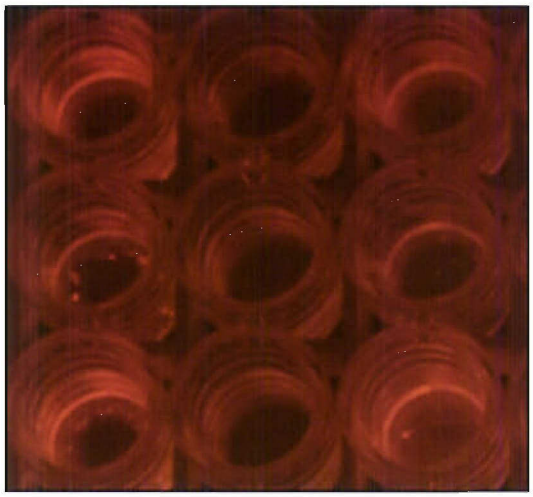
Surface Biological Threat Detection Using DNA and Quantum Dots

Payoff

AFRL developed a system to detect biological threat agents using deoxyribonucleic acid (DNA) aptamers, also called DNA capture elements (DCE), conjugated to quantum dots in a molecular beacon-like molecule. DCEs are versatile molecules that can be selected to recognize unique motifs of biological threat agents such as anthrax, tularemia, smallpox, and Shiga toxin. These quantum dots are nanocrystals that emit visible light in a narrow bandwidth but can be excited using light of broad bandwidth.

Accomplishment

AFRL successfully demonstrated that a DCE selected against Shiga toxin could detect Shiga toxin on a surface and differentiate between Shiga toxin and another protein. Microtiter plate wells were used to simulate a surface. Either Shiga toxin, bovine serum albumin (BSA), or a mixture of the two proteins was bound to the surface of the wells. Using these wells, scientists determined that a DCE quantum dot complex was able to discriminate between Shiga toxin and BSA. When wells with BSA were treated with DCE quantum dot complex, little or no fluorescence was observed.



Fluorescence is proportional to the amount of DCE quantum dot complex or antibody bound to the target molecule. In turn, the amount bound is proportional to the concentration of the target molecule. The DCE quantum dot complex was detected at a lower sensitivity setting than the fluorescein-labeled antibody.

While it is difficult to compare the signal from the quantum dot to an organic fluor because of differences in the instrument's sensitivity towards each fluor, quantum dots offer advantages over organic fluors because of their brightness, resistance to photo bleaching, and requirement for only one excitation wavelength. Furthermore, only 1.2 micrograms of DCE were used per well compared to 20 micrograms of antibody. This experiment indicates that DCEs conjugated to quantum dots can detect biological threat agents on a surface.

Background

The Air Force Special Operations Command requested a system from AFRL to identify biological threat agents contaminating a surface. AFRL scientists designed a beacon-like system consisting of the DCE conjugated to a quantum dot and the complementary strand (DCEs are single-stranded DNA) containing the quencher. When the biological threat agent that is the target of the DCE is present, the complementary strand with the quencher is displaced, permitting fluorescence to occur. A model of this system using an organic fluor was successfully tested against spores using a flow cytometer. The reported success is not of the entire beacon but verifies that DCEs can bind to a biological threat agent on a surface and that the quantum dot provides a strong signal.

GIP and SIFT Test and Evaluation Successful

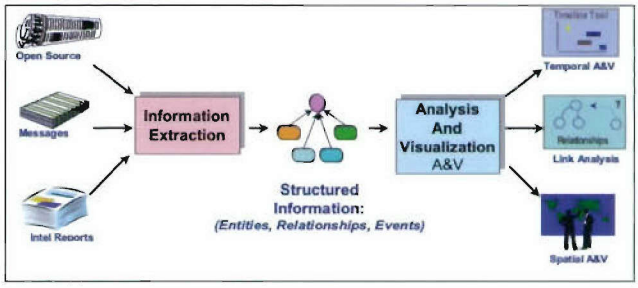
Payoff

Since 9/11, intelligence communities have sifted through mountains of information from text documents containing communications and human intelligence in an effort to extract and exploit information that can identify, locate, and track targets in hiding and in the open. AFRL developed information extraction software to help make this monumental task easier and reduce man-hours in message processing.

Accomplishment

The AFRL Information Directorate conducted a 2-week test and evaluation (T&E) of information extraction text processing tools at the Headquarters US South Command (SOUTHCOM) Joint Intelligence Center (JIC). AFRL information extraction software was integrated into an operational setting and processed previously unseen intelligence messages. Seven JIC analysts actively participated in the evaluation, and several others observed.

The laboratory-developed software packages are the Generic Intelligence Processor (GIP) and Statistical Information From Text (SIFT). GIP is a modular, reconfigurable environment for constructing message processing applications capable of extracting data from intelligence messages and outputting the extracted data in a format that can be readily exploited by other analytical systems or databases. SIFT is a statistically based, train-by-example system used to extract entities and relationships between them in running text.



Background

As a result of the T&E, SOUTHCOM generated an after-action report stating AFRL's information extraction tools displayed the potential to save man-hours in message processing for database production. An annex to the report listed several enhancements/requirements that the software must meet prior to operationalizing the applications in the SOUTHCOM production environment. AFRL engineers are analyzing the report annex to determine the feasibility and costs involved in meeting the requirements.

AFRL Engineers Assess Cold Spray Coating Processes

Payoff

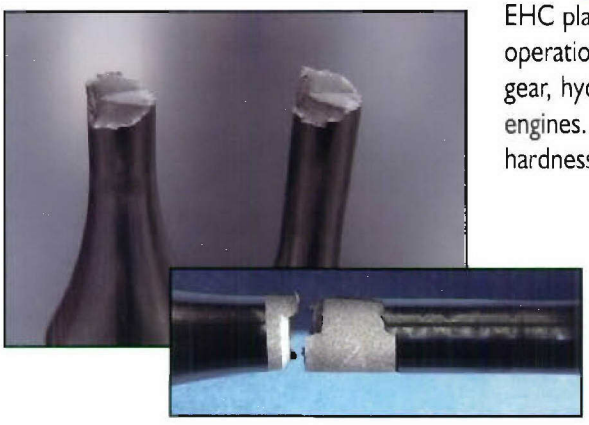
Cold spray deposition technologies have demonstrated promise in providing a successful method for applying alternative, environmentally advantaged coatings to aerospace components. Engineers from AFRL's Pollution Prevention Group and Materials Test and Evaluation Group conducted a short-term, cost-effective evaluation of five candidate cold spray technologies that ranged from university research studies to commercially available processes.

Due to the favorable results of this initial evaluation, continued testing and validation of the technologies will be conducted. These new tests could yield a solution to environmental compliance, hazardous waste disposal, and worker safety challenges that the Air Force faces with the current electrolytic hard chrome (EHC) coatings and their application processes.

Accomplishment

AFRL Materials and Manufacturing Directorate engineers identified two cold spray deposition technologies that may be used to apply tungsten carbide-cobalt (WC-Co) coatings without the spalling and delamination shortcomings associated with high-velocity oxygen fuel (HVOF) thermal-sprayed coatings. If follow-on testing is successful, these technologies have the potential to help the Air Force (AF) find a suitable alternative to EHC plating operations, which are plagued by growing environmental compliance and waste disposal problems.

Coating, integrity, and metallurgical evaluations determined that two of the commercial processes successfully provided a WC-Co coating to high-strength steel specimens. Unlike the previously observed performance of HVOF applied coatings, cold- sprayed coatings did not spall or delaminate when subjected to stresses in the higher operating range of the substrate material.



Background

EHC plating is used extensively during AF Air Logistics Center maintenance operations to rework, rebuild, and repair worn components of aircraft landing gear, hydraulic cylinder actuators, propeller hub assemblies, and gas turbine engines. Chrome plating provides beneficial metallurgical properties such as hardness, wear resistance, corrosion resistance, and lubricity.

However, EHC involves the use of hexavalent chromium, which is a known carcinogen. Federal and state regulatory agencies strictly control its use and disposal, which has resulted in increased disposal costs, increased liability, and risk for the AF.

The AF and other Department of Defense organizations are currently investigating the use of HVOF thermal spray technology to replace EHC plating. AFRL has conducted several projects involving the demonstration and validation of HVOF thermal spray coatings that have helped to determine the technology's capabilities and limitations.

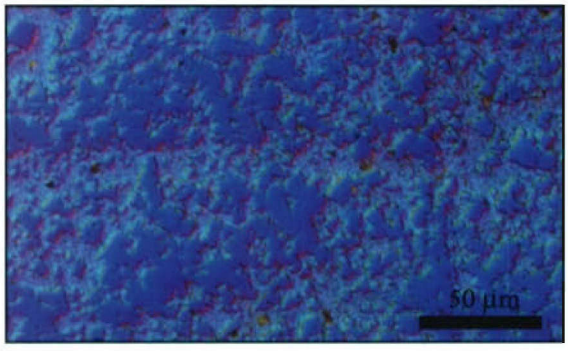
During AFRL testing, engineers determined the ability of each of the cold spray deposition processes to successfully apply WC-Co powder to steel substrates and evaluated the ability of the coating to remain firmly attached when the substrate was subjected to stresses in its higher operating range. An extensive demonstration and validation follow-on project was developed to further evaluate the coatings produced by these two processes.

Be-Al Alloys Reduce Weight of Spacecraft Components and Provide Greater Stiffness Than Conventional Materials

Payoff

Beryllium-aluminum (Be-Al) alloys help reduce the weight of vital spacecraft components while increasing payload and/or performance. AFRL's Materials and Manufacturing Directorate research program has increased the technology base and demonstrated cost-effective manufacturing capabilities in prototype components derived from a detailed collaborative design process.

These advances will benefit the space program and national security and could lead to important applications in the commercial sector. Continued research in this promising area will lead to expanded applications and streamlined manufacturing processes, as well as significant cost reductions for the Air Force and Department of Defense.



Accomplishment

AFRL scientists and engineers, working with industry, demonstrated the feasibility of using Be-Al alloys to fabricate component parts for spacecrafts. The project team succeeded in producing multiples of near-net-shape and net-shape parts and in joining subassemblies to make complex structures like those used on spacecraft.

AFRL is engaged in a dynamic research and development effort as part of the Metals Affordability Initiative (MAI), designed to extend the use of Be-Al to both primary and secondary structural space applications. Be-Al alloys investigated under this program cover a Be content range of 35%-65% by weight, with a focus on materials with lower Be contents, to better manage costs. The Be-Al MAI program succeeded in increasing the technology base and established cost-effective manufacturing capabilities for fabricating prototype components.

The project team successfully formulated and demonstrated the worthiness of a detailed collaborative design process and the feasibility of producing near-net-shape and net-shape parts. They joined subassemblies to make complex structures and made significant progress in materials development, component selection and design, and component fabrication and testing. A major accomplishment of this research and development effort was the successful production of multiples of two important structural components.

Background

Be-Al alloys have been used in a number of high-performance applications, such as gas turbine engines, racing cars, space launch vehicles, and satellite structures, due to a unique combination of low density and high stiffness. The specific strength and stiffness characteristics of Be-Al exceed those of traditional titanium alloys. These properties enable reduced structural weight and increased payload and/or performance. Be-Al is also of interest as a replacement for pure Be because it offers much greater stiffness than Al alloys at lower material cost than pure Be and improved formability, enabling fabrication into near-net shapes and further cost reductions.

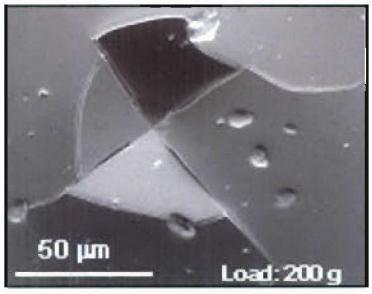
The project team is comprised of spacecraft original equipment manufacturers (OEM) and material suppliers. Within the collaboration, OEMs are responsible for design and component validation, and material suppliers have the lead role in developing cost-effective manufacturing technologies.

Advancements in Super-Tough Nanocomposite Coatings Point to Improved Aircraft Engine Performance and Durability

Payoff

AFRL Materials and Manufacturing Directorate scientists and engineers, working with university researchers, have made substantial progress in the understanding of super-tough nanocomposite coatings. These new coatings could be used to improve the performance and durability of advanced jet fighter aircraft engine components.

As a result of this research effort, AFRL is exploring new application possibilities within the Air Force and seeking avenues to transfer the new materials to the aerospace community. One possible transition path leads to the use of nanocomposite coatings in short takeoff and vertical landing (STOVL) propulsion system components, where friction pairs are heavily preloaded and can benefit significantly from surface strengthening.



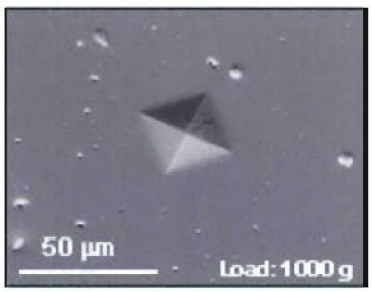
Accomplishment

The team identified a dynamic mechanism unique to nanocrystalline/amorphous composites, highly valued by aerospace engineers for their extreme hardness. The research has led to increased opportunities for transitioning new materials to combat aircrafts, a Small Business Innovation Research (SBIR) Phase I program to improve the structural and performance capabilities of aircraft propulsion systems, and a number of possible commercial applications.

Background

AFRL researchers initially developed a new class of wear-resistant materials for friction pairs of air and space vehicles. These materials are made of very hard, 3–5 nanometer (nm)-sized grains of carbides or oxides embedded into an amorphous matrix of either diamond-like carbon or a metal/ceramic mixture. During this preliminary stage, the research revealed an unusual combination of high hardness, exceeding that of ceramics, and fracture strength similar to that of tough metal alloys.

Building on this discovery, AFRL teamed with university researchers to set up one-of-a-kind experiments. New composite materials could be mechanically tested inside a transmission electron microscope column to observe with nanometer-level resolution what mechanisms are responsible for the unusual combination of mechanical properties.



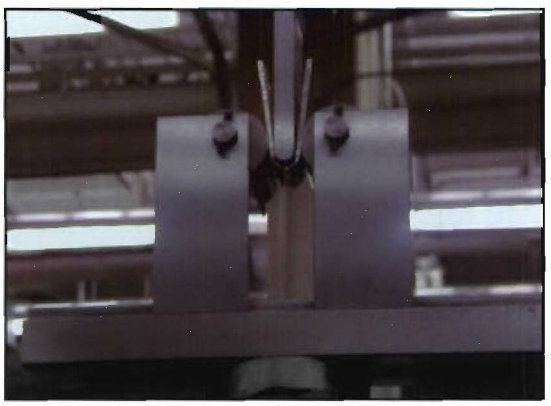
As a result of this investigation, a new mechanism of macroscopic ductility was found for these tough nanocomposites. This new mechanism is a unique feature of nanocrystalline/amorphous composite design since it is tied to a great number of 1–2 nm shifts of nanograins inside an amorphous matrix.

The experimental results of this research effort explain the high fracture toughness of nanocrystalline/amorphous composites at extreme contact deformations with high loading rates. Currently, AFRL scientists and engineers are exploring a wide range of nanocomposite coatings application possibilities for military aircrafts. They are also searching for innovative technology transfer opportunities. One transfer possibility involves the use of nanocomposites in STOVL frictional propulsion system components. An SBIR program has been initiated to address this opportunity.

AFRL Engineers Evaluate NLOS Hard Chrome Alternatives

Payoff

Implementation of a non-line-of-sight (NLOS) hard chrome alternative for the coating of aircraft engine and landing gear components will help to eliminate growing environmental compliance and disposal problems associated with hard chromium plating. An alternative technology that can be easily incorporated into Air Force (AF) Air Logistics Center (ALC) maintenance operations is expected to significantly reduce worker exposure to carcinogenic materials.



Accomplishment

Engineers from the AFRL Materials and Manufacturing Directorate's Pollution Prevention Group are conducting a project funded by Air Force Materiel Command Weapon Systems Pollution Prevention program to identify, demonstrate, validate, and implement alternatives to electrolytic hard chrome (EHC) plating processes for parts that have NLOS coating requirements. The project is designed to complement the use of high-velocity oxygen fuel (HVOF) thermal spraying of tungsten-carbide cobalt.

HVOF technology is the primary coating process the AF is transitioning to replace hard chromium plating. However, it is limited to line-of-sight applications and cannot accommodate components with internal surfaces, blind holes, and complex geometries.

Background

EHC plating is used extensively to rebuild, rework, and repair worn components during the overhaul of aircraft engines and landing gear assemblies. EHC plating provides a coating with desirable metallurgical properties such as hardness, wear resistance, corrosion resistance, and lubricity. However, EHC plating involves the use of hexavalent chromium, which is a known carcinogen, and its use and disposal are strictly controlled by federal and state regulatory agencies. Implementation of these regulations has resulted in higher disposal costs and increased liability and risk for the AF.

The AF and other Department of Defense organizations are currently transitioning HVOF thermal spray technology to replace EHC plating. However, the process is limited to line-of-sight applications for parts having simple shapes and no internal surface coating requirements. Therefore, the process is not able to coat 20%–40% of aircraft engine and landing gear components.

To date, hardness, profilometry (smoothness of coating), composition, quality and Taber wear testing of vendor-supplied coatings has been accomplished. Additional evaluations will be conducted, including corrosion resistance, fatigue, hydrogen embrittlement, wear, grindability, and strippability.

The ALC plating shops at Tinker Air Force Base (AFB), Oklahoma, and Hill AFB, Utah, have been active participants in the decision-making process from the beginning and will eventually plate-test specimens with the best performing coating in order to prove that an acceptable coating can be applied in a production environment. The final phase of this project will be the development of an ALC implementation plan that will facilitate the transition of the new process into maintenance operations. The project is expected to be completed by 2005.

Laser Surface Pretreatment Method for Metal Adhesive Bonding

Payoff

The AFRL Materials and Manufacturing Directorate developed testing to demonstrate the use of a handheld laser that could eliminate laborious, time-consuming surface pretreatment activities associated with conventional surface preparations for aircraft metal bonding, including composite patch repairs. Laser surface pretreatment minimizes worker exposure to hazardous materials because the process generates no waste other than that of the aircraft coating, which is ablated as flakes are vacuumed into a container for disposal.

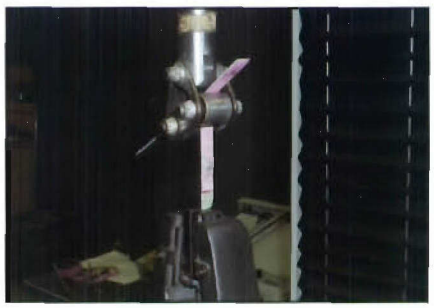
Accomplishment

AFRL engineers demonstrated that a low-power, handheld laser system can be used to pretreat aircraft surfaces before sol-gel adhesive bonding surface preparation. Extensive testing conducted with a prototype laser system proved the extreme promise of this technology as a method for removing organic coatings and contaminants from aluminum surfaces in an environmentally friendly manner. The laser provided the surface morphology and texture necessary to achieve acceptable bond strength and moisture durability when used with an environmentally friendly sol-gel treatment.

If the results of further testing prove positive, the system may offer significant advantages to maintainers conducting aircraft structural repairs. The Department of Defense and commercial industry have identified lasers as a potential environmentally friendly alternative to using chemical paint strippers and sandblasting.

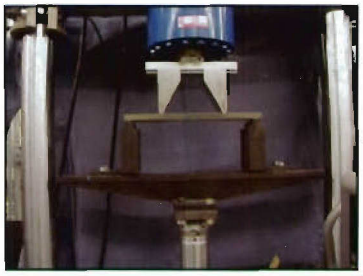
Background

The Air Force Materiel Command Weapon Systems Pollution Prevention program funded AFRL's testing. The project engineers initially optimized and evaluated the system's ability to remove organic coatings and to texturize and clean the surface so that it would be suitable for bonding activities. They demonstrated that the technology was an environmentally friendly alternative to chemical stripping, hand sanding, grit blasting, and solvent cleaning of metallic surfaces. Wedge, lap-shear, and peel-resistance testing also showed that acceptable bond strength and moisture durability could be attained on surfaces contaminated by baked-on hydraulic fluid.



AFRL recently initiated a follow-on project to evaluate the handheld laser's removal capabilities in small areas and to provide the surface morphology required for acceptable aircraft-bonded repairs. Once again, engineers will use the water-based and hexavalent chrome-free, sol-gel technology as the bonding treatment. The final phase of this project will evaluate the laser's ability to prepare titanium and composite surfaces for adhesive bonding.

Engineers Evaluate High-Velocity Oxygen Fuel Coatings for High-Temperature Applications



Payoff

Implementation of an electrolytic hard chrome (EHC) alternative for the rebuild, rework, and repair of worn turbine engine components will help to minimize the growing environmental compliance and disposal problems associated with the use of hexavalent chromium. Reduction of the use of chromium during Air Force (AF) Air Logistics Center maintenance operations will result in a significant reduction of worker exposure to this carcinogenic material.

Accomplishment

Engineers from the AFRL Materials and Manufacturing Directorate conducted a project funded by the Air Force Materiel Command Weapon Systems Pollution Prevention program to evaluate high-velocity oxygen fuel (HVOF) thermal-sprayed coatings as an alternative to EHC for elevated temperature applications. HVOF technology is the primary coating process that the AF is implementing to replace hard chrome plating. During this project, engineers evaluated the high-temperature metallurgical properties of HVOF and plasma-sprayed coatings, specifically tungsten carbide-cobalt (WC-17Co), Tribaloy 400 (Co-29 Mo-8Cr), and Diamalloy 3007 CrC20 (Ni20Cr) to determine their suitability as alternatives to EHC for gas turbine engine applications.

The results of this investigation demonstrated that the performance of HVOF-applied coatings is superior to that of plasma-sprayed coatings and equal to or better than that of EHC for the substrates and coatings evaluated. This project will help to facilitate the transition of HVOF coating technology into AF depot maintenance operations.

Background

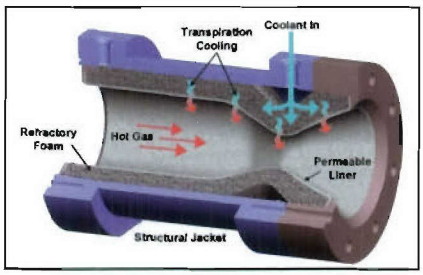
EHC plating is extensively used to rebuild, rework, and repair worn components during the overhaul of aircraft turbine engines. EHC plating provides a coating with desirable metallurgical properties such as hardness, wear resistance, corrosion resistance, and lubricity. However, EHC plating involves the use of hexavalent chromium, a known carcinogen. Federal and state regulatory agencies strictly control the use of hexavalent chromium, resulting in higher disposal costs and increased liability and risk for the AF.

The AF and other Department of Defense organizations are currently transitioning HVOF thermal spray technology to replace EHC plating. The Aeronautical Systems Center's Propulsion Environment Working Group (PEWG) is working with the major aircraft turbine engine manufacturers to transition HVOF coating technology. The AFRL Pollution Prevention Group established the high-temperature HVOF applications project to complement the PEWG program by providing in-depth materials and metallurgical analysis of the elevated temperature performance of HVOF-applied coatings and the effect of the process on the substrate being coated.

Researchers Develop Transpiration Cooling Concept

Payoff

The AFRL Materials and Manufacturing Directorate developed a transpiration-cooled thrust chamber concept as part of the Integrated High-Payoff Rocket Propulsion Technology (IHPRPT) program. This concept consists of three major parts: a porous inner liner, an intermediate foam coolant plenum, and an outer structural jacket.



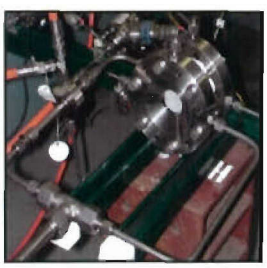
Researchers expect this new technology to reduce the weight of current, actively cooled thrust chambers by 50% and significantly reduce system complexity, part count, cost, and coolant volume. Reducing the weight of rocket engines will enable increased payloads, potentially saving millions of dollars in launch costs.

Accomplishment

AFRL scientists and engineers partnered with Ultramet, a small business in Pacoima, California, to develop and demonstrate transpiration cooling concepts and materials that could lead to lightweight, high-efficiency combustion chambers for rocket engines. By replacing conventional cooling concepts and materials with lightweight ceramic or metallic foams coated with a porous transpiring ceramic or metallic liner, researchers expect to reduce the weight and cost of future liquid-fueled rocket engines.

Background

In a liquid-fueled rocket engine such as the space shuttle main engine, the engine injects a fuel (in this case, liquid hydrogen) and an oxidizer (liquid oxygen) into a thrust chamber, where they mix and react. The fuel/oxidizer reaction products are high-temperature gases, which expand through a nozzle, producing thrust.



Combustion takes place at temperatures in excess of 6000°F, which is higher than the melting point of conventional engine materials. Therefore, the engine must cool the chamber materials with the continuous flow of a fluid that carries heat away from the chamber walls. In this case, the hydrogen fuel also serves as the coolant fluid.

Current state-of-the-art thrust chambers are comprised of an inner copper liner with machined cooling channels, a thin layer of nickel to close out the channels, and an outer nickel-based alloy structural jacket. During operation, the engine pumps hydrogen coolant through the channels in the copper liner to keep it from melting. The current thrust chambers are heavy, complex, and expensive, and they also require large amounts of cooling.

Researchers collaborating as part of this IHPRPT program expect to demonstrate a combustion chamber concept using high-temperature materials and transpiration cooling methods that can significantly improve performance while reducing weight and cost. The transpiration-cooled thrust chamber concept consists of a porous inner liner, an intermediate foam core, and an outer jacket for structural support.

Advances in propulsion achieved during this effort will advance the goals of the IHPRPT program. The program will improve the nation's capability to move into full-scale development of rocket propulsion systems with improved performance, affordability, operability, reliability, and maintainability.

Advancements in Predicting Composition of Metallic Glasses Aid in Future Technologies

Payoff

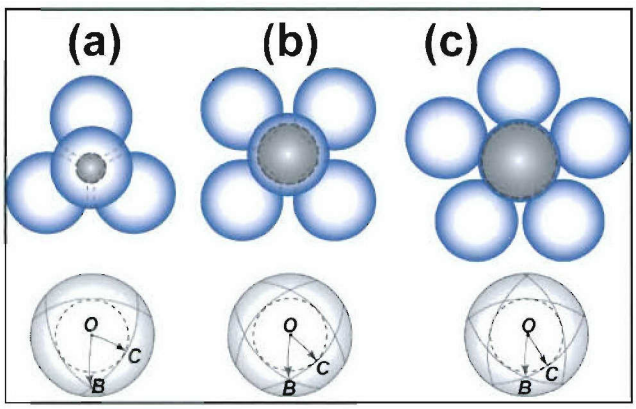
AFRL scientists have made significant advancements in the development of bulk metallic glasses that can be used to improve the durability and performance of aerospace components. These advancements will enable the Air Force (AF) to develop metallic glasses with the exceptional functional properties (i.e., magnetic and structural) required to meet the demands of tomorrow's crucial technologies. The research effort contributes directly to the development of tougher, high-performance aerospace components and benefits not only the AF, but also commercial aviation and industry in general.

Accomplishment

The AFRL Materials and Manufacturing Directorate spearheaded these advancements. Scientists have succeeded in creating working scientific models capable of predicting the composition of new metallic glasses, thus helping researchers determine in advance whether or not the glasses can be manufactured in bulk. As a result of AFRL's research, several new bulk metallic glasses were discovered in the past year. The work has also led to the successful development of a new technique for illustrating the topology of amorphous (noncrystalline) metal alloys.

Background

Metallic glasses have tremendous potential as materials with exceptional functional properties such as their magnetic and structural qualities. However, most metallic glasses have to be cooled very quickly at rates faster than about 1000°C/second. Subsequently, one dimension of the material produced is typically less than 0.5 mm to achieve these high cooling rates. Only a few bulk metallic glasses exist with critical cooling rates low enough to produce bulk pieces of 1 mm or more.



Unfortunately, after 40 years of research in metallic glasses, there is no reliable way to predict new bulk metallic glass compositions. Over the past 2 years, AFRL scientists conducted research that provided models based on the number and sizes of atoms that lead to a useful predictive capability. Several new bulk metallic glasses have already been discovered as a result of this effort.

The high density of amorphous alloys, relative to the crystalline form of the same alloy, leads to the proposal that efficient atomic packing is a fundamental consideration in the constitution of metallic glasses. Previous efforts to explain the high relative density of amorphous metals based on dense random packing of atoms of different sizes have been unsuccessful. AFRL researchers have taken the approach to explore the concept of efficient atomic packing based on atomic clusters consisting of a central solute atom surrounded by solvent atoms in the first coordination shell.

The ratio, R, of the solute atom radius to the solvent atom radius is the only topological parameter considered. A simple analysis of this model leads to the conclusion that specific atomic radius ratios, R*, provide efficient atomic packing over a length scale defined by these atomic clusters. This result extends earlier descriptions of the influence of topology on the formation of metallic glasses by providing a more specific set of conditions for metallic glass formation.

AFMC Chooses ICE™ for Analysts at Development and Logistics Test Centers

Payoff

An integrated computer tool named Integrated Cost Estimation (ICE) is being used for cost analysis on weapon systems including aircraft, spacecraft electronics, munitions, and engine systems. Analysis that formerly took weeks to accomplish can now be completed in a few hours with ICE.

This tool enables the analyst on any technology or system development or modification project to include cost as an important consideration during design trades, helping to ensure new technologies and systems are affordable. The system's ability to show in minutes the cost savings of one technology choice compared to another will enable decision makers to focus efforts and resources in their search for better performance at more affordable life-cycle costs.

Accomplishment

The AFRL Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division, with participation from the AFRL Information Directorate, managed the program that developed the ICE tool. The Air Force Materiel Command (AFMC) purchased the tool for use throughout its systems acquisition-related organizations. The purchase of ICE will save AFMC up to 90% of the time required to provide an effective cost analysis capability.

ICE enables personnel, both cost experts and nonexperts at AFMC centers and laboratory facilities around the country, to use the tool as a computerized cost estimating systems that reduces the time required for weapon systems cost estimates from months or days to hours or less. The tool offers selection of the best value design or system alternative by providing credible cost estimation results from integrated Department of Defense (DoD)-accepted cost models and weapon systems operations and support data.

Background

Concepts and technologies for military systems have historically been evaluated based primarily on performance. Air Force leaders emphasize affordable systems and technologies to increase performance, reduce costs, or extend the operational life of a system. The need for more affordable systems requires tools to assess the life-cycle cost and affordability of a system before funding is prioritized and assigned by the weapon systems technology development manager.

ManTech and Frontier Technology, Inc., developed the current design of the ICE tool 4 years ago under a Small Business Innovation Research project. With continuing development funded by both AFMC's Aeronautical Systems Center and AFRL, ICE evolved into a robust, collaborative cost tool, providing a capability to credibly estimate the development, production, and operations/support costs for DoD systems.

This successful technology is used within AFRL and AFMC program offices to help analysts and managers understand the cost implications of design and acquisition decisions, thus helping to ensure new technologies and future systems are affordable. The capability is also enabling managers to justify and effectively support existing project funding levels and support future funding requests by providing return-on-investment assessments and a credible business case analysis for the project.

Advanced Composite Materials Could Play Key Role for Aerospace Mirrors

Payoff

The next generation of defense missions relies on enhanced aerospace surveillance and reconnaissance, directed energy systems, transformational communications, laser radar systems, and large telescopes operating from the infrared through the X-ray frequency spectrum. All of these applications will require low-cost, lightweight, high-precision mirrors.

The launch and flight payload constraints are often determined by the size, shape, operational environment, and configuration of these mirrors, which are mission specific. Advanced composite materials will improve mirror strength and toughness, reduce their weight, and expand their operational life, while shortening production schedules and reducing costs.

Accomplishment

Researchers at the AFRL Materials and Manufacturing Directorate are helping to identify new materials and manufacturing processes needed to build these critically important, highly advanced aerospace mirror systems. The key system drivers in all of these applications are mass, cost, production schedule, robustness, and optical quality.

Background

Monolithic glass is the state-of-the-art material for aerospace mirrors. It can be formed into complex shapes, ground to high precision, and polished to an Angstrom-level surface finish. It is used in both ambient air and space conditions, as well as in cryogenic applications, because its coefficient of thermal expansion (CTE) can be chemically tailored to be near 0 ppm/°C. This minimizes distortion of the optical surface caused by thermal excursions during service. The Advanced Mirror System Demonstrator (AMSD) program demonstrated that the monolithic glass mirrors can be lightweight, with an areal density around 15 kg/m^2.

The mirror fabrication cost and schedule were half that of the Hubble Space Telescope under the AMSD program. The next generation of mirror technologies will likely use hybrid and/or composite mirror designs that replace glass as the mirror structural substrate, thereby reducing the areal density while improving the material robustness. These advanced concepts rely on composite materials (metal, ceramic, and polymer), foams, and microsphere arrays. Recent materials advances have made possible small-size flat mirrors with areal densities less than 7 kg/m^2. These materials also allow for CTE and modulus tailoring; have low density; and exhibit high strength, stiffness, and toughness. The novel structural substrates can be clad with a homogeneous material of similar CTE, such as glass, silicon, or silicon carbide, and then polished to optical tolerances.

AFRL's research is focused on reducing—by at least half—the weight, cost, and production schedule for aerospace mirrors and doubling their robustness. The basic approach is to combine hybrid/composite structural substrates with optical surfaces produced either by replicated foil technology or by polymer spinning technology. Both of these approaches require materials that are CTE-matched in order to obtain and keep the correct contour and smoothness of the optical surface during fabrication and operation.

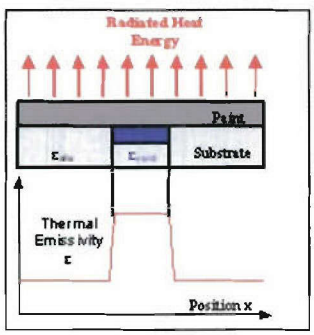
Nanosized, negative CTE particles that can be uniformly dispersed into several types of material are being fabricated. This family of CTE-matched materials can then be used to construct replicated hybrid/composite mirrors for Department of Defense and National Aeronautics and Space Administration applications.

Passive Thermographic Imaging Shows Promise for Detecting Hidden Corrosion

Payoff

Scientists and engineers at the AFRL Materials and Manufacturing Directorate have made significant advancements in the development of a reliable method to identify hidden corrosion under aircraft paint. The ability to image relatively large surface areas on aircraft would represent a significant advancement in AFRL's measurement capabilities, reduce inspection time, and lower costs.

The results of this research effort demonstrated the potential of a passive thermography system to provide a fast, reliable, and extremely simple capability for detecting and characterizing hidden corrosion under paint. Continued research could lead to the development of a new system that significantly improves the corrosion inspection process while reducing the risk of failure in aircraft structural components.



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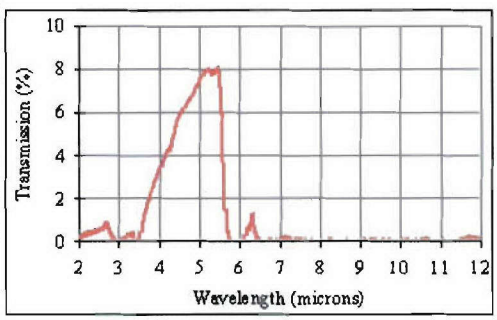


1B

Accomplishment

AFRL researchers, employed a passive thermographic technique to assess the detailed microscopic features of hidden pitting corrosion samples. They studied variations in sensitivity, detectivity, and spatial resolution while focusing on the passive thermographic technique's ability to detect the hidden corrosion and provide additional information on the microscopic nature of the corrosion area, its roughness, material loss levels, and pitting sharpness. The experimental technique provided images of hidden corrosion areas and demonstrated the capability to assess internal structures.

Background

Corrosion costs the Air Force (AF) in excess of $800 million per year to detect and treat. Much of this expense is due to scheduled maintenance activities that often require stripping the paint off aircraft or completely disassembling component parts for inspection. These aggressive maintenance procedures are needed to ensure corrosion is not present in structural components, which could compromise the structural integrity of the aircraft if left unchecked. The availability of a quick, reliable, and simple nondestructive evaluation (NDE) technique to detect and characterize corrosion hidden under aircraft paint would go a long way towards reducing inspection times and costs and, ultimately, improving flight safety.

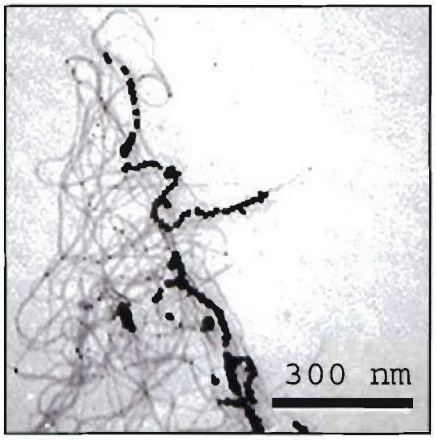
Thermographic imaging is a relatively new NDE technology that uses the thermal differences between a material defect and its local surroundings as a noncontact and full-field NDE measurement tool. Infrared (IR) cameras with higher sensitivities and resolutions are helping to transform this technology into a comprehensive and quantitative measurement tool.

In certain instances, the thermographic measurements can be made in a spectral band-pass window that allows the IR energy to propagate efficiently through a coating layer to probe the material substrate underneath. This was the case for the standard AF gray primer topcoat paint used in the set of studies. By using a special midwave IR camera sensitive to 3-5 micron thermal energies and/or using band-pass filters in that wavelength range, AFRL scientists and engineers are able to image corrosion regions directly through the paint.

Biomineralization Research Could Have Far-Reaching Impact on Materials Development and Air Force Applications

Payoff

Inorganic materials, minerals in particular, perform a vital role in military and commercial systems because of their favorable electronic and thermal properties. The ability to control their formation could revolutionize materials science by enabling development of new materials and low-temperature processing techniques using environmentally friendly materials. The knowledge gained from biomineralization research could also have a far-reaching impact on materials development and applications for the Air Force (AF), national defense, and the aerospace industry.



Accomplishment

AFRL Materials and Manufacturing Directorate research scientists, working with associates at Genencor, Inc., and Trinity University in San Antonio, Texas, made significant advancements in the quest for new materials for advanced structures using processes borrowed or adapted from living organisms. One of their principal areas of concentration is biomineralization, the biological process by which organisms form minerals used to make hard tissues such as bone, teeth, and shell. Working at the billionths-of-a-meter scale, the researchers successfully demonstrated that various types of minerals can be created via laboratory experimentation (*in vitro*) and that the size, shape, and other defining characteristics of the crystals that form them can be partially controlled.

Background

A mineral is a naturally occurring homogeneous inorganic substance with a specific chemical composition and a characteristic crystalline structure, color, and hardness, like gold or silver, or a mixture of inorganic compounds, like granite. In living organisms, minerals make up hard tissues like bones and teeth and, for some organisms, a protective shell. The mineral crystals ("biominerals") formed by living organisms are created at physiological temperatures; hence, the ability to mimic the transformation of inorganic molecules into nano- and microstructured components *in vitro* at low temperatures provides a critical incentive for the AF materials science research community.

AFRL research supports the notion that biomineral properties, such as particle size, shape, crystal orientation, polymorphic structure, defect texture, and particle assembly, can be controlled or at least partially controlled. This control is exercised through specialized proteins that recognize specific crystal surfaces during the growth of the crystals. Recognition is based on complementarity between the protein and the crystal structure on defined planes at the molecular level.

Scientists have capitalized on some of these concepts to produce novel materials. The self-organizing ability of amphiphilic molecules, for example, was used to direct the nucleation and growth of inorganic materials precipitated in their presence, such as in the fabrication of mesoporous ceramic thin films, organized arrays of nanoparticles, and microlaminated structures. Biopolymers and their synthetic analogues are used in industrial processes requiring water treatment and particle manipulation. Some examples are polypeptides used as biodegradable dispersants, flocculents, absorbents, antiscalants, and crystal growth modifiers.

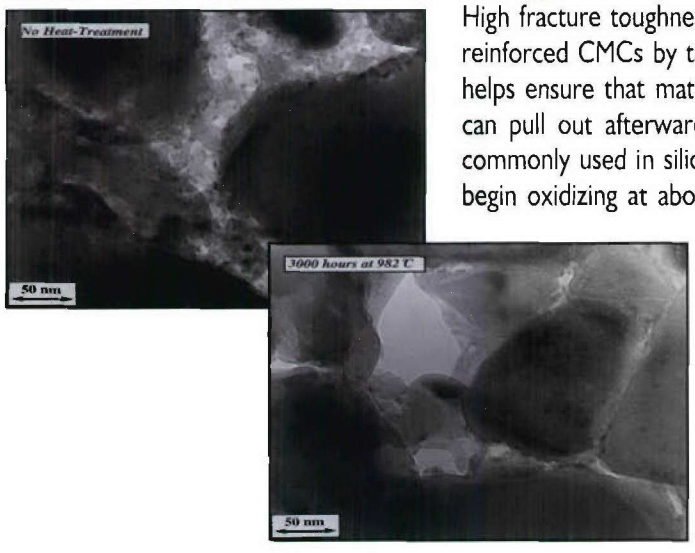
Ceramic-Matrix Composites Research Advances Aerospace Applications Development

Payoff

Scientists at the AFRL Materials and Manufacturing Directorate made significant gains characterizing and understanding the high-temperature mechanical behavior of fiber-reinforced ceramic-matrix composite (CMC) materials used in aerospace structural applications. This research helps advance the creation of new technologies for the commercial sector and national defense and contributes to natural science through improved understanding of CMCs and in particular, the behavioral properties of oxide-oxide composites.

Accomplishment

AFRL researchers examined four main characteristics of a porous-matrix composite developed for aerospace by General Electric. Their evaluations resulted in a greater understanding of these materials and their potential applications for both military and commercial aerospace products and innovations.



Background

High fracture toughness and damage tolerance are engineered into most fiber-reinforced CMCs by tailoring the properties of the fiber-matrix interface. This helps ensure that matrix cracks can be deflected around fibers and that fibers can pull out afterwards. Carbon and boron nitride are the interfaces most commonly used in silicon-carbide-fiber CMCs. Unfortunately, carbon coatings begin oxidizing at about 450°C, and the gap left by the oxidation can fill with silica, forming a strong fiber-matrix bond that seriously degrades the mechanical properties of the CMCs.

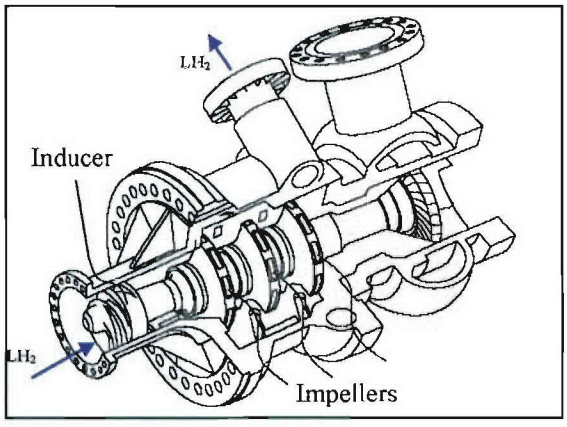
AFRL scientists examined GEN-IV (N610/AS), one of several porous-matrix oxide-oxide CMCs developed by General Electric for high-temperature aerospace applications. N610/AS consists of 3M Nextel 610™ fiber and an aluminosilicate matrix. The in-house research team investigated four key characteristics of N610/AS composites: (1) long-time phase and microstructural stability; (2) high-temperature, short-time stress-strain response; (3) fatigue; and (4) creep and creep rupture. The researchers also compared N610/AS composites with other CMCs in order to formulate possible explanations for the composites' behavior. They found reasonable tensile strength and fatigue performance at both room and high temperatures in the N610/AS CMC. They determined that tensile and compressive strength are moderate at room temperature compared with other CMCs, but unlike most other CMCs, fatigue performance does not change significantly with temperatures up to 1000°C.

The Nextel 610 fiber had low creep resistance and limited use time above 1000°C. The low modulus, porous, and precracked aluminosilicate matrix had low in-plane and interlaminar strength. The mechanisms by which composite mechanical properties degrade above 1000°C were found to be related to both fiber and matrix degradation mechanisms.

Super-High-Strength Aluminum Alloy Developed for Cryogenic Applications

Payoff

Scientists at the AFRL Materials and Manufacturing Directorate's Integrated High-Payoff Rocket Propulsion Technology (IHPRPT) program developed a super-high-strength aluminum (Al) alloy to improve the performance and capability of aerospace components, specifically for cryogenic rocket engine applications. The Al alloy is significantly less expensive, more resistant to hydrogen embrittlement, and 38% lighter than the conventional titanium alloys currently used in propulsion systems. At full scale, scientists expect the alloy to be appropriate for additional applications, streamline manufacturing processes, and provide cost reductions to benefit the Air Force, Department of Defense (DoD), and industry.



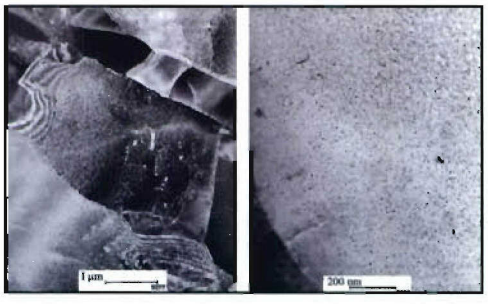
Accomplishment

AFRL scientists successfully achieved an alloy with specific strength and ductility characteristics that surpass those of the alpha titanium alloy currently used in rocket engine turbopump impellers. The Al alloy demonstrates less sensitivity to hydrogen, a weight advantage, and the tremendous potential for cost savings related to its manufacturing and maintenance, as compared to the titanium alloy.

AFRL scientists and engineers demonstrated the feasibility of using the super-high-strength Al alloy to fabricate component parts for spacecraft propulsion. The project team achieved desired properties during testing with half-sized, subscale preforms. They have produced alloy castings 76 mm in diameter and 6 m long.

Background

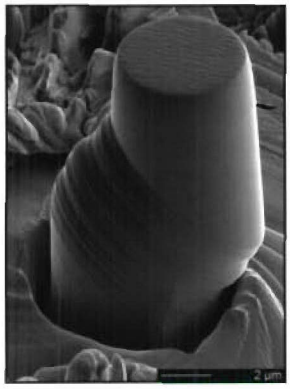
In 2001, the AFRL Materials and Manufacturing Directorate collaborated with Universal Energy Systems (UES), Inc., under a Small Business Innovation Research program funded by the AFRL Propulsion Directorate, to research and develop efforts designed to meet requirements of the IHPRPT program. Their goal is to improve thrust-to-weight ratio in rocket engines by identifying an Al alloy with specific strengths that equal or exceed those of the high-strength titanium alloy used for turbopump impellers. The Al alloy also requires a significant reduction in weight under conditions of no less than 7% ductility.



IHPRPT is a DoD-, National Aeronautics and Space Administration-, and industry-coordinated effort that provides maximum connectivity among various propulsion activities. The goal of the program is to develop revolutionary and innovative technologies by the year 2010 that will enable a doubling of rocket propulsion capabilities over 1993 state-of-the-art technology. The program will improve the nation's capability to move into full-scale development of rocket propulsion systems with improved performance, affordability, operability, reliability, and maintainability.

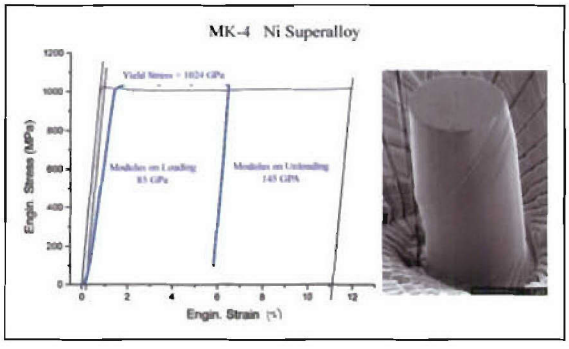
Spin-off IHPRPT programs are planned to determine whether the super-high-strength Al alloy may have a broader impact on aerospace applications. Researchers will evaluate whether the alloy can be used to produce turbopump housing and whether it can provide an appropriate replacement for stainless steel pipes within a liquid rocket engine.

Advanced Method for Characterizing Nickel-Based Alloys Improves Material Design Capability



Payoff

Scientists at the AFRL Materials and Manufacturing Directorate, in collaboration with Pratt & Whitney Aircraft and General Electric Aircraft Engines, invented a new method for characterizing the single-crystal properties of nickel-based alloys. The integration of advanced mechanical property measurements, materials representation, and simulation methods will reduce time for new materials insertion and will transfigure "materials" into a design variable for engineered systems. These advancements will benefit combat systems and readiness.



Accomplishment

AFRL developed the new method under the Defense Advanced Research Projects Agency Accelerated Insertion of Materials (AIM) program. The new approach uses focused ion beam (FIB) microscopy and was developed concurrent with a test method based on nanotechnology. Further development of these methodologies, in conjunction with continued integration of simulation methods devised under the AIM program, will permit the direct use of microstructure in the engineering design process.

The new method uses FIB milling to isolate and prepare single-crystal mechanical test specimens from individual grains or constituents from a conventionally processed alloy. Once prepared, specimens transfer to a conventional nanoindenter device outfitted with a flat-punch indentation tip. Employed to test the microsamples in uniaxial compression, the nanoindenter provides high-fidelity load-displacement measurements as the samples deform.

The development of this novel mechanical behavior test capability allows researchers to sample local mechanical effects of material microstructure, which can be statistically incorporated within a complete simulation of critical component features. The key objective is dramatically reduced insertion time.

Background

One primary challenge to the rapid insertion of materials is the need to understand both the intrinsic properties of an engineering material and the influence of defects on the material's overall macroscopic behavior. Historically, no capability existed to develop model parameters or validate continuum materials behavior models based upon discrete microstructural information. Continuum crystal plasticity methods are at the frontier of techniques that incorporate direct microstructural information. However, a major deficiency in these models resides in the inability to obtain required input information. This is particularly true when such parameters must reflect the subtleties of material process history or the local influence of defects.

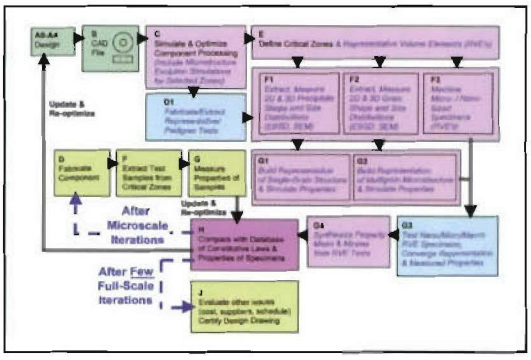
Predicting Microstructure Performance Streamlines Material Design Process

Payoff

Scientists at the AFRL Materials and Manufacturing Directorate, assisted by Universal Energy Systems (UES), Inc., developed a framework for accelerating development of structural materials used to build aerospace components. The proposed methodology will accelerate the development of advanced materials, especially those with novel or previously unexplored properties, towards component insertion. This is accomplished through rapid assessment of material-intrinsic properties, as well as the local material response to extrinsic defects, in the context of component design cycles. The new method extends to all aspects of material design, especially structural material design, and designs using materials where properties at small-length scale are important.

Accomplishment

AFRL and UES developed a testing methodology and simulation framework for structural materials that incorporate the local, microscopic, and submicroscopic heterogeneous nature of material properties directly into design procedures. This new approach builds upon a number of rapid microstructural and property assessments of local regions of a material, including single-crystal regions, defected regions, and grain aggregates. It is part of the Accelerated Insertion of Materials program, managed by the Defense Advanced Research Projects Agency and the Air Force, and is designed to reduce and eliminate costly, time-consuming, extensive testing and analysis.



AFRL's approach defines the parameters within a hierarchy of mathematical and numerical representations of a sample material and can be used in design performance simulation codes to predict the intrinsic response of larger-scale structures. The new methodology can also be used to predict the impact of defects on full-scale structures performance. Most of the steps can be automated, and the methodology as a whole can reduce the number of large-scale cycles required for qualifying a material's suitability for structural service.

Background

Microstructures of most alloys are very sensitive to processing variables, and the properties of alloys are sensitive to material microstructure. Unfortunately, significant variations in microstructures are typically found within a component due to factors beyond control during large-scale processing. These variations tend to make component design difficult. Mechanical design methodologies come from established physical laws that parameterize the known world into physically measurable quantities and responses. The behavior of the materials is included in these design methodologies and parameterized as continuum-level mathematical representations in the form of validated constitutive laws for macroscopic aggregates.

AFRL's approach seeks to provide a framework that enables rapid assessment of material structural capability in a component to facilitate design and insertion. This methodology is unique, since it does not rely solely on macroscopic testing of artificial configurations that approximate the material of interest. Instead, it uses the same common hierarchical process for both synthetic materials and samples extracted from full-scale production devices, as needed.

Combined Agent Firefighting System Successfully Evaluated for Use in Antarctica

Payoff

AFRL Materials and Manufacturing Directorate scientists and engineers from the Fire Research Group designed and prototyped the Combined Agent Firefighting System (CAFFS), which bridges the gap between flight-line fire extinguishers and crash/rescue fire trucks. This project is one of several research and development efforts currently being transitioned by the Fire Research Group that demonstrates the Air Force's dedication to providing firefighters with specialized equipment and technologies required to counter unique fire threats.

Accomplishment

At the request of Dr. Harry Mahar, of the National Science Foundation, United States Antarctic Program, AFRL successfully demonstrated at McMurdo Station, Antarctica, the first self-contained, foam-based firefighting system to operate in subfreezing temperatures without the use of internal or external heating. Dr. Mahar, who is the safety and health officer for operations in the Antarctic, was particularly interested in the lightweight, deployable firefighting technology developed by the laboratory for cold-weather application. Typical crash trucks on hand for response to aircraft fires are large and heavy, and require constant heating to prevent freezing.

Background

Air Mobility Command provides air logistical support for US scientific missions in the Antarctic, landing aircraft on any of the three ice runways at McMurdo Station, which is the hub for all operations to the South Pole. During the height of operations, two runways may be operated simultaneously, causing a strain on the limited firefighting resources available. Firefighting equipment must be designed to withstand extreme cold weather and rugged terrain. Typical conditions at McMurdo Station dictate equipment operation to -40°F and storage to -60°F.

CAFFS uses compressed-air foam and dry chemical potassium bicarbonate dual-agent technology to extinguish pool and running fuel fires. The agents can be used separately or in combination, depending on the type and size of emergency. The entire unit is roughly one-ninth the size and weight of a P-19 crash/rescue fire truck, which makes it both compact and easily deployable.

Specialized aqueous film-forming foam was used in the system, which enabled it to work in temperatures down to -40°F without freezing. AFRL engineers traveled to McMurdo Station to further demonstrate the system and to train the McMurdo Fire Department on its use. Engineers plan to study the system upon its return to determine any lasting effects of the low temperature, humidity, and volcanic ash.

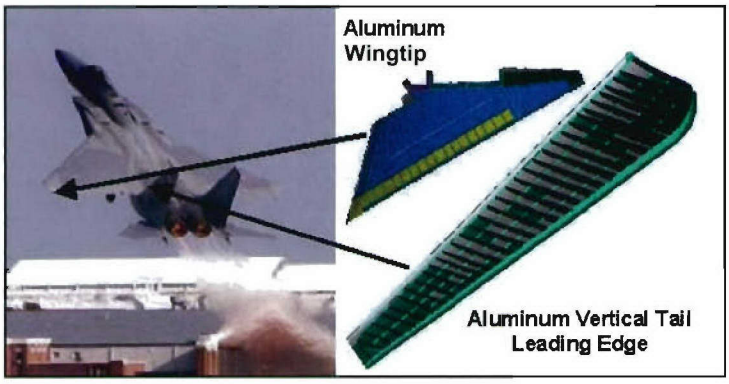
Engineers from the Fire Research Group are also working with the Air Armament Center's Air Base Systems Division to produce the system and possibly make it available commercially. If CAFFS continues to perform well in colder temperatures, it may be evaluated at the South Pole, where temperature requirements are as low as -60°F for operation and -100°F for storage.

Affordable Machining Program Targets Cost Reductions in Aerospace Components

Payoff

AFRL Materials and Manufacturing Directorate scientists and engineers, in a collaborative effort with researchers from industry and major universities, made significant advancements in the development of analytical tools and advanced machining technologies for aerospace components. Since machined products primarily come from a supplier base, benefits will be realized through reduced prices and shorter delivery times.

Technology innovations and insights realized under the Affordable Machining Program (AMP) effort are applicable wherever metallic structural components, turbine blades, and actuators are used.



Accomplishment

The AMP addresses customer needs by providing low-cost, high-quality machined parts for aircraft components. Working together under AMP, the team dramatically improved the parts quality of the F-15's vertical tail leading edge and wingtip using state-of-the-art, high-speed machining techniques and stable cutting parameters, and by replacing the forged material stock used to build these components with stress-relieved plate stock. These innovations result in a calculated $16 million cost savings for the Air Force.

Tangible benefits include reduced machining time, scrap and rework rates, and tooling and assembly fixtures, along with increased part accuracy and quality. Intangible benefits include more complex machined-component designs for increased affordability (through parts unitization) and reduced inventory.

Background

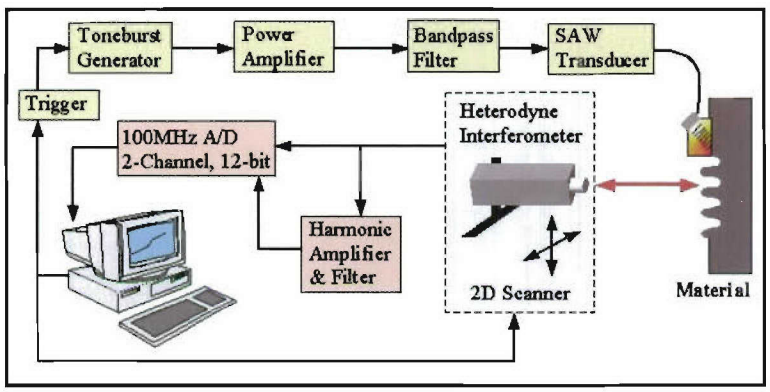
The purpose of AMP is to develop and implement analytical tools and advanced machining technologies to enable lower-cost fabrication of machined aerospace components. AMP is a cost-shared program funded by the Metals Affordability Initiative and industry. Primary team members include AFRL, Boeing, Carpenter Technology, Northrop Grumman, and Rolls-Royce. The subcontractors include Cincinnati Machine, TechSolve, Third Wave Systems, Vykor, the University of North Carolina at Charlotte, the University of Florida, and Washington University.

Because the team is focusing on existing and pervasive wrought material forms such as plate, bar, and forgings, additional time and expense to certify components is not necessary. Their proposed technologies will also reduce the time to market for machining modifications by increasing confidence in the process before it hits the shop floor. This, in turn, will reduce first article lead times by providing improved first-time quality and lower production lead times by increasing reliability and accuracy. The participation of material suppliers and the machine tool industry in the program further enhances pervasiveness. These entities have the incentive to provide the technology to as many producers as possible. In addition, the technology partnership is involved in a range of applications to further distribute the technology throughout industry.

AFRL Develops Ultrasonic System to Revolutionize Nondestructive Evaluation

Payoff

Scientists at the AFRL Materials and Manufacturing Directorate developed a prototype nonlinear laser ultrasonic nondestructive evaluation (NDE) system that can measure and assess localized fatigue damage in a material with high sensitivity and resolution. This effort will provide a means for the Air Force and the Department of Defense to assess high-performance weapon systems for the entire life of each system. It will enable more efficient system maintenance, reduced costs, greatly improved reliability, and longer in-service life sustainment.



Accomplishment

AFRL's ultrasonic NDE system provides a means for visualizing the fundamental and harmonic displacement fields of propagating surface and bulk acoustic waves. The system proved to be highly effective for assessing the local fatigue state in several different metallic substrate materials used in aerospace systems. Continued research and development efforts will serve to revolutionize NDE by facilitating the ability to follow the fatigue state of critical structural components from beginning to end.

Background

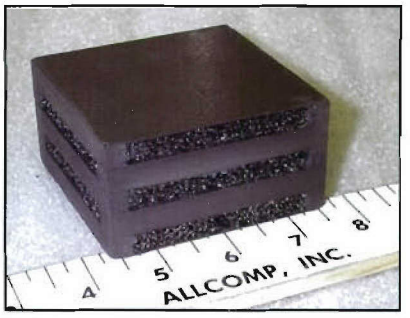
AFRL scientists developed a nonlinear laser ultrasonic system and used it to characterize the fatigue state of a fractured Ti-6Al-4V sample with high spatial resolution and sensitivity. The measurement system they employed was built around a scanning heterodyne interferometer, which creates detailed displacement field images for propagating surface and bulk acoustic fields on a material surface. They assessed the local fatigue damage to the sample using nonlinear ultrasonic interaction principles, where the local amplitudes of the fundamental and second harmonic displacement fields are monitored simultaneously.

Building on this progress, the team developed a prototype nonlinear laser ultrasonic NDE system that can image the fundamental and harmonic ultrasonic displacement fields in several material substrates. Their measurements included nonfatigued and fatigued materials (titanium, aluminum, and nickel superalloys).

AFRL Develops Advanced Materials For Aerospace Thermal Management Applications

Payoff

Advanced heat exchanger applications offer the potential for reduced weight, improved performance, increased aircraft payload, and reduced material and life-cycle costs. Carbon foam heat exchangers are predicted to weigh 50% less than conventional high-temperature metallic core precooler and heat exchanger designs. They are also expected to increase the efficiency of all existing metal heat exchangers and prototype carbon-carbon composite units from 85% to 90%, which is a significant impact. This technology may be adopted in a wide range of thermal management applications for advanced high-power electronics and government and commercial air and ground vehicles.



Accomplishment

AFRL scientists and engineers, working in tandem with Allcomp, Inc., and Touchstone Research Laboratory, Ltd., completed the first phase of a Small Business Innovation Research (SBIR) effort to determine the feasibility of providing an enhanced-strength carbon foam core for medium-temperature heat exchanger applications, using either outside ram air or new approaches with engine fan duct air. The team determined the strength, thermal, and pressure drop requirements for a typical bleed air precooler, developed a model for predicting the heat exchanger core envelope and weight, tested and screened candidate materials, and developed and fabricated a subscale prototype hybrid foam heat exchanger with a predicted performance that exceeds the capabilities of metallic exchanger designs. The methods to form thin-wall, high-density plate fins (a component of the exchanger) were also successfully developed.

Background

Carbon foam is widely recognized as a revolutionary material that AFRL engineers expect to have a tremendous impact in the area of thermal management for aerospace and space applications. The Air Force is interested in processing and manufacturing this novel material for its lighter-weight components, providing solutions to a variety of issues generated from traditional carbon-fiber-reinforced and composite and metallic materials.

During the SBIR effort's second phase, the proposed heat exchanger, with a cross-flow compact design using advanced high conductivity core materials such as carbon-carbon and carbon foam, will be further optimized. Design optimizations will be conducted to create a balanced design that meets thermal, structural, and mass requirements simultaneously.

MINT Improves Antijam Performance for GPS Satellite Tracking

Payoff

The Global Positioning System/Inertial Navigation System (GPS/INS) integration algorithms developed under the Miniature Integrated Navigation Technology (MINT) program provide more antijam performance for GPS satellite tracking compared to conventional code and carrier loops. MINT is effective against all jammer types by optimally processing inertial measurement unit (IMU) data with raw GPS measurement data. This new technology will enable future GPS/INS guided weapon systems to accurately navigate closer to targets protected by higher levels of radio frequency interference.

Accomplishment

The AFRL Munitions Directorate's Navigation and Control Team, located at Eglin Air Force Base (AFB), Florida, managed the MINT program. MINT increased the jamming resistance of a GPS/INS without adding dedicated antijam electronics. MINT pushed the state of the art in navigator design by incorporating a low-cost microelectromechanical sensor IMU, a GPS receiver with a selective availability/antispoofing module, and an ultratightly coupled GPS/INS integration algorithm. The MINT program demonstrated accurate navigation in environments with jammer-to-signal ratios over 70 dB during extensive ground testing at Eglin AFB and flight testing at the Boeing facility in St. Louis, Missouri.

Background

Researchers from AFRL's Navigation and Control Team worked with Boeing, Draper Laboratory, and Honeywell engineers to demonstrate this new technology aboard the mobile test vehicle at Eglin AFB and aboard the Boeing King Air aircraft in St. Louis, Missouri. MINT demonstrated high GPS jamming immunity in a small, low-cost package. Future GPS systems, particularly for weapons delivery, will benefit from the optimal integration of GPS receivers with inertial measurement units and the use of adaptive processing algorithms and antennas that reject unwanted signal interference while maximizing the power of the desired satellite signal.

Campus Challenge: Hard, Deeply Buried Target Neutralization

Payoff

The AFRL Munitions Directorate devised and manages the Campus Challenge problem-solving competition. The competition leverages AFRL's investment in revolutionary technologies by engaging a limited number of top engineering schools in a 2-year competition to arrive at the most efficient solution to a munitions-related technical problem. The competition is structured to solicit innovative, potentially paradigm-shifting ideas to successfully address these problems. The Campus Challenge is a "win-win" for both AFRL and participating schools.

Accomplishment

AFRL's inaugural Campus Challenge problem involved defeating a hardened, deeply buried target such as an enemy command, control, and communication facility. The objective was to derive one or more innovative methods to neutralize the operation of a well-defended, hardened, deeply buried facility located within an unfriendly country. Emphasis was placed on methods and technologies that could neutralize such a facility for the long term (at least 6 months) and that could be delivered to the facility or in its vicinity by current or projected Air Force delivery platforms. These innovative methods were to be based on emerging technology or on technology reasonably expected to be available by 2016.

The Phase I winners were the University of Delaware and the University of Scranton. Both Phase I winners submitted a detailed technology roadmap as the final product and culmination of the Campus Challenge competition. Each university was awarded an 8-month, $150,000 contract to support the research necessary to design its respective technology investment roadmap. AFRL's selection committee reviewed the final technology investment roadmaps and chose the University of Scranton as the Phase II, or ultimate, winner of this inaugural Campus Challenge.

Background

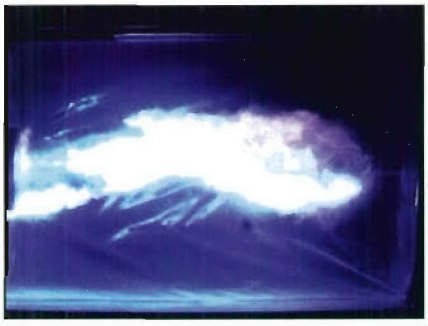
Colonel Michael Ruff, the former director of the AFRL Munitions Directorate, presented the Okaloosa Sword to the winning team from the University of Scranton. The Okaloosa Sword is an actual battle-worthy weapon representing armament superiority from another era. The sword is symbolic of a Campus Challenge victory, and its presentation conveys the importance the directorate places on these Campus Challenge competitions.

AFRL's Campus Challenge initiative is a recurring event. The second Campus Challenge focuses on a different real-world problem and has different participants than the first. But the charter will always be the same—a challenge to match wits in devising solutions to real problems through the advent of paradigm-shifting technology.

Patented Explosive Firing Set Unleashes ElectroExplosive Studies

Payoff

Mr. Mark Heyse, Mr. Ron Stearns, and Dr. Alex Cash, of the AFRL Munitions Directorate, were issued a patent entitled "High Voltage Tolerant Explosive Initiation." They patented an explosive firing set that allows ultra-high-voltage events to be safely integrated with explosive charges.



Accomplishment

The AFRL team designed, fabricated, and tested the new firing set; verified that it met all technical requirements; and obtained safety board approval for use. The high-voltage-tolerant firing set allows research in unexplored areas such as electroexplosive effects. AFRL is using the firing set to study novel initiation methods in volumetric explosives (the use of small amounts of electrical or mechanical energy to initiate, control, and direct the release of chemical energy from thermobarics and fuel-air explosives).

AFRL is studying methods to tune blast characteristics by applying electrical energy to explosively formed ionized channels, shock waves, and reaction zones in fuel-air mixtures. Using this equipment, AFRL personnel successfully demonstrated a crude "dial-a-yield" capability in small-scale, proof-of-concept tests with acetylene-air mixtures.

Background

AFRL required a firing set to initiate detonators in ultra-high-voltage experiments, but commercial firing sets did not have adequate high-voltage isolation. The patented design uses nonmetallic fiber-optic cables, pneumatic controls, battery isolation, and redundant safety devices to withstand hundreds of thousands of volts.

Scramjet Engine Ground Testing Successfully Completed

Payoff

AFRL Propulsion Directorate researchers completed wind tunnel testing of the world's first fuel-cooled supersonic combustion scramjet, an engine that uses conventional jet fuels to reach hypersonic speeds (speeds over Mach 5). AFRL researchers and their industry partners successfully demonstrated the operability and durability of the scramjet at two representative flight Mach numbers (Mach 4.5 and Mach 6.5).

Accomplishment

AFRL successfully completed freejet testing of the first-generation supersonic combustion scramjet engine, known as the ground demonstration engine (GDE-1). Testing was conducted as part of the Aerospace Propulsion Division's Hypersonic Technology (HyTech) program. GDE-1 is a flightweight, fuel-cooled, hydrocarbon scramjet ground test engine that was designed and built by Pratt & Whitney and tested at General Applied Sciences Laboratory facilities in Ronkonkoma, New York.

The next step in the development process is to design, fabricate, and test the second-generation engine, known as GDE-2. Testing goals include closed-loop operation of the engine in a ground test environment. GDE-2 will be slightly larger, include a variable geometry inlet, and be regeneratively fuel-cooled during testing, meaning that the fuel used to cool the engine will also be burned in the combustor. Testing of GDE-2 will take place at the National Aeronautics and Space Administration Langley Research Center's 8-foot high-temperature tunnel.

Background

The HyTech program was started in the wake of the cancelled National Aerospace Plane program, an effort aimed at developing a hydrogen-fueled, scramjet-powered, single-stage-to-orbit vehicle capable of aircraft-like horizontal takeoffs and landings. In contrast, the Air Force's version of the scramjet is designed to run on JP-7 fuel, a more logistically supportable fuel than hydrogen. This technology has the potential to power future hypersonic vehicles, such as cruise missiles and long-range strike and reconnaissance aircraft, at speeds up to eight times the speed of sound.

Test Stand Ready for New Rocket Development

Payoff

One of the nation's largest rocket development and test stands is part of the AFRL Propulsion Directorate's nearly $3 billion worth of facilities and equipment at Edwards Research Site, providing the nation and the Air Force (AF) with rocket propulsion research, development, and test capabilities. Test Stand 2-A is the only Department of Defense (DoD) stand capable of performing full-scale rocket thrust chamber development testing in the 750,000 lb thrust class. Testing next-generation rocket engine components on Test Stand 2-A is intended to provide more reliable, lower-cost, and higher-performance rocket engines for future missions.

Accomplishment

Originally designed and built more than 30 years ago for Apollo's moon-mission F1 rocket engine development and testing, the test stand was given an 18-month modernization and state-of-the-art enhancements, making it the most modern large rocket test stand in the DoD. Its primary use will be the development of advanced rocket engine turbomachinery and combustion components, but it can also be utilized for other high-pressure and flow-rate propulsion systems.

Background

Major General Paul D. Nielsen, former AFRL commander, participated in the ribbon-cutting ceremony with other AF officials. During the ceremony, Gen Nielsen stated, "This lab's vision statement states, 'We defend America by unleashing the power of innovative science and technology.' There is probably no technology we work on that exhibits that power as much as rocket propulsion power." Nearly every American rocket-propelled satellite, missile, or launch vehicle has been touched by the technology research, development, or testing conducted at AFRL's Edwards Research Site.

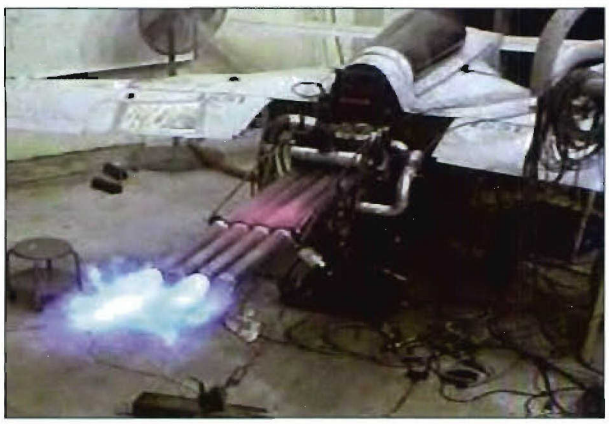
AFRL's Pulsed Detonation Engine Completes Ground Testing

Payoff

The AFRL Propulsion Directorate's pulsed detonation engine (PDE) successfully completed ground tests while installed in an amateur-built, experimental airframe and running on common general aviation-grade gasoline, demonstrating proof of concept. The tests met the Federal Aviation Administration certificate requirements for the future manned-flight test phase program.

Accomplishment

AFRL completed ground testing of its PDE, designed and built in house. This milestone highlights AFRL's many significant achievements in this technology. The 20-hour test program marked the first pure PDE sustained and controlled operation.



Background

AFRL established the PDE program to focus on the potential uses and benefits of detonating engine technology over conventional deflagrating engines. A few program goals were to generate nonproprietary PDE data for government use, develop detonation methodology for common aviation fuels without the need to use dangerous and expensive pure oxygen or solid explosive detonation initiators, and establish a research baseline for future Air Force PDE technology development programs.

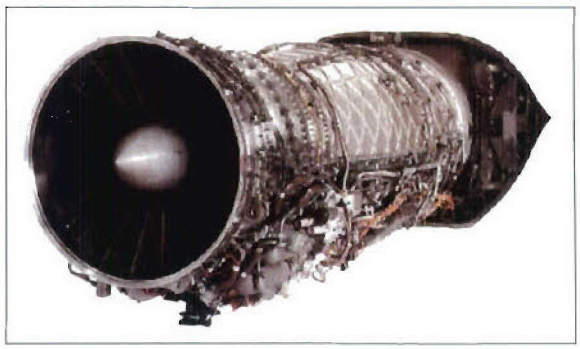
Revolutionary Analysis Conducted on F119 Engine

Payoff

The AFRL Propulsion Directorate successfully used advanced probabilistic analysis to quantify and assess variations in engine structural behavior. Probabilistic design approaches are rapidly being integrated into engine design and development processes to assure that optimum structural efficiencies and durability requirements are achieved.

Accomplishment

AFRL utilized advanced probabilistic analysis to quantify variations in the F119 engine's structural behavior. The analysis predicted engine structural behavior over a large region of design space and defined the test results with greater accuracy than conventional analysis methods.



The test results found significant variations in the dynamic behavior of the engine structure that were caused by manufacturing variations in geometry. By accounting for this variation during test data processing, engineers will be able to reduce measurement errors and provide a more accurate determination of component behavior and a component-predicted service life assessment.

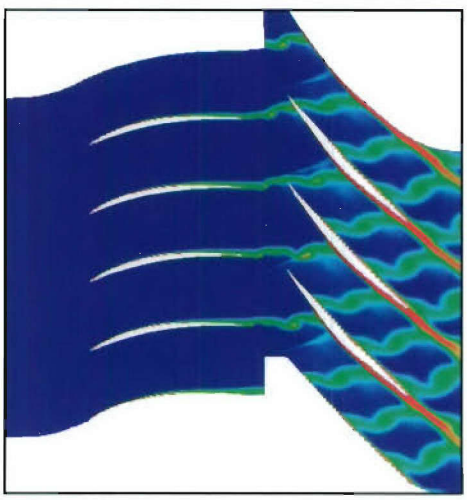
Background

The probabilistic analysis of the F119 engine structure is part of the Integrated High-Performance Turbine Engine Technology program. AFRL coordinated the analysis approach and findings with Pratt & Whitney test engineers to allow probabilistic analysis to be applied to future design processes.

AFRL Demonstrates M&S Application in Turbine Engine Development

Payoff

AFRL Propulsion Directorate scientists use high-performance computing (HPC) and modeling and simulation (M&S) capabilities to analyze components under development and to impact turbine engine design and manufacturing decisions in a short time frame. The M&S application will reduce the number of engine design iterations required and provide predictions of component performance, thus reducing the need for expensive and time-consuming system testing.



Accomplishment

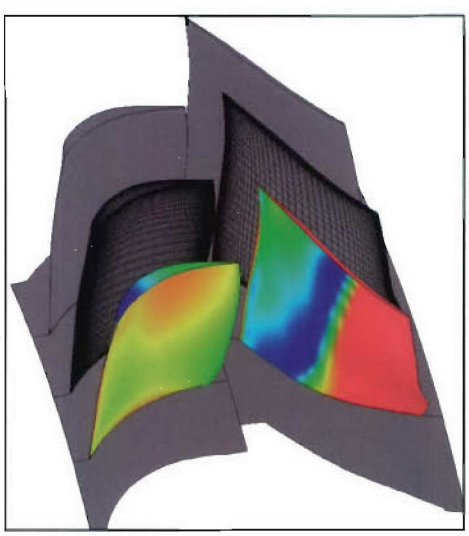
AFRL scientists teamed with the Aeronautical Systems Center (ASC) Major Shared Resource Center (MSRC) and General Electric Aircraft Engines (GEAE) and successfully demonstrated the use of a time-accurate computational fluid dynamics (CFD) code that analyzed advanced compression systems. Simulations on four cases, each having a different boundary condition, were accomplished. Nine blade passages were modeled in three dimensions, requiring a total of 22 million grid points.

The data provides the capability to analyze and understand unsteady airflow phenomena so that intelligent design choices can be made to improve efficiency in new-development jet engine compressors, combustors, and turbines. This effort demonstrated the utility of HPC resources to allow critical technologies to be discovered and applied to advanced turbine engine development programs at a much faster pace.

Background

The use of M&S is a key AFRL approach to address the affordability of advanced turbine engines. ASC MSRC provided the computation resources and the software, and TURBO was the CFD code used. TURBO's principal architect was Mr. J.P. Chen, of Mississippi State University and the National Aeronautics and Space Administration (NASA) Glenn Research Center, and GEAE provided the program funding and upgrades.

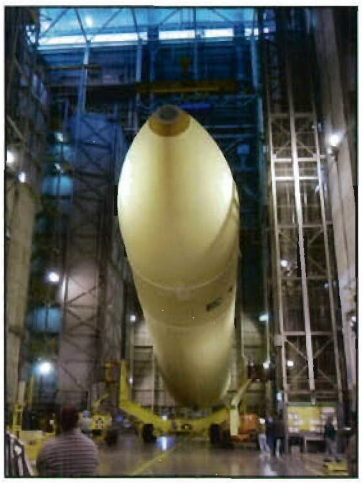
Researchers conducted the demonstration in support of the Versatile Affordable Advanced Turbine Engines (VAATE) program. VAATE is a joint Department of Defense, NASA, Department of Energy, and industry effort seeking to achieve a tenfold improvement in turbine engine affordability by 2017. VAATE will also transition advancing turbine engine technologies to legacy and pipeline systems.



T-Ray Technology Contributes to Space Shuttle Return to Flight

Payoff

The AFRL Propulsion Directorate's T-Ray Technology program is making significant contributions to assist the National Aeronautics and Space Administration (NASA) to achieve a milestone to return the space shuttle to flight. AFRL's in-house researchers and Picometrix, Inc., of Ann Arbor, Michigan, developed the T-Ray 2000™ system under the Small Business Innovation Research program.

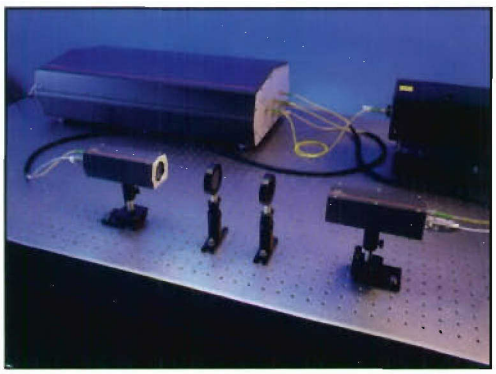


Accomplishment

The T-Ray 2000 system is a commercial terahertz radiation system that performs far-infrared spectroscopy, sensing, and imaging. NASA plans to use T-Ray 2000 units to inspect the space shuttle external fuel tanks' spray-on foam insulation (SOFI). This system earned both the prestigious Research and Development 100 Award and Photonics Spectra's Circle of Excellence Award.

Background

NASA's Langley Research Center purchased one system for use in its Nondestructive Evaluation Laboratory. Five additional units were ordered for nondestructive inspections of the space shuttle external tank SOFI at the Michoud Assembly Facility, in New Orleans, Louisiana.



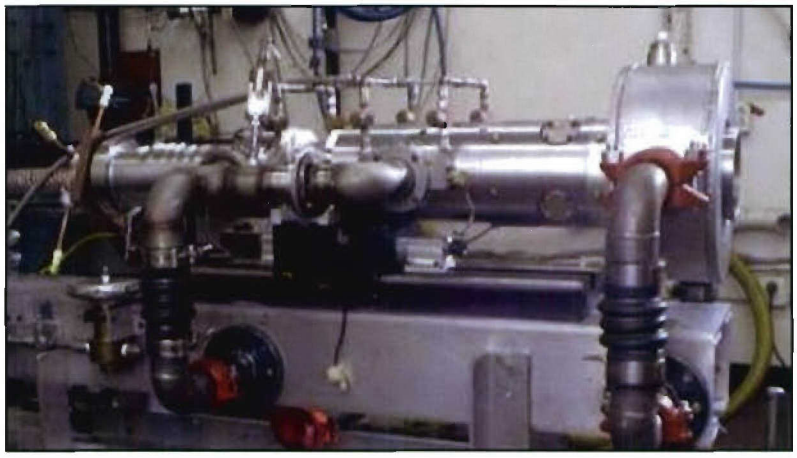
Critical Pulsed Detonation Engine Experiment Completed

Payoff

AFRL Propulsion Directorate scientists completed in-house testing of a Boeing pulsed detonation engine (PDE) in AFRL's High-Pressure Combustion Research Facility at Wright-Patterson Air Force Base, Ohio. The test results will provide a benchmark for performance and will be used for validating models and simulations over a wide range of conditions. These tests will also be used to guide future development of advanced propulsion systems considered by the Air Force.

Accomplishment

The tests evaluated PDE performance at higher pressure and temperature conditions. This critical PDE experiment validated the performance advantages predicted for PDEs at supersonic speeds over a much broader range of simulated altitudes, flight speeds, and compression ratios. At the same time, researchers collected data to evaluate the use of pulsed detonation combustion in a turbine/PDE hybrid cycle. During this testing, Mach 2.7 conditions were successfully reached for pure PDE operation, and Mach 1.8 conditions were reached for hybrid test cycles.



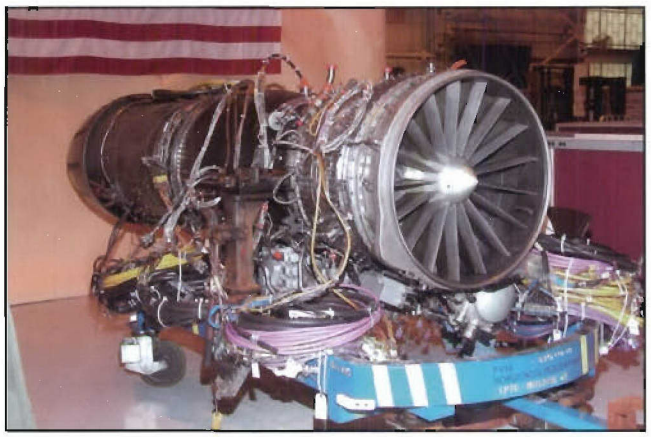
Background

AFRL's PDE team has been involved in experimentation and testing of PDE technology for several years in both internal PDE development programs and industry collaborative efforts. Originally developed by the Boeing Company with National Aeronautics and Space Administration funding, the engine was previously tested at Boeing Phantom Works at low pressures and temperatures in order to study PDE acoustics and operability at altitude.

Structural Turbine Engine Demonstrator Completes Major Test Milestone

Payoff

The joint Air Force/Navy XTE77/SE1 demonstrator engine successfully completed high-cycle fatigue (HCF) model validation testing at the General Electric test facility in Lynn, Massachusetts. The results of the AFRL Propulsion Directorate's engine demonstrator test will have a direct effect on lowering the risk associated with HCF in advanced engine development efforts such as the Joint Strike Fighter's F136 engine.



Accomplishment

HCF is a phenomenon associated with turbine engine operation that produces vibratory stress cycles induced from various electromechanical sources. HCF has historically led to premature failure of major turbine engine components. The XTE77/SE1 demonstrator engine is based on the F414 design, utilizing advanced technologies such as a forward-swept second-stage fan, low-excitation front frame, six-stage three-dimensional aerodynamic compressor, and high-pressure turbine with single-crystal MX4 blades.

Data derived from testing this highly instrumented engine will be used to validate key elements of the HCF test protocol developed under AFRL's Integrated High-Performance Turbine Engine Technology (IHPTET) program. The demonstrator completed 59 hours, 39 minutes of the test run. Post-test borescopic inspection of the hot section found it to be in excellent condition.

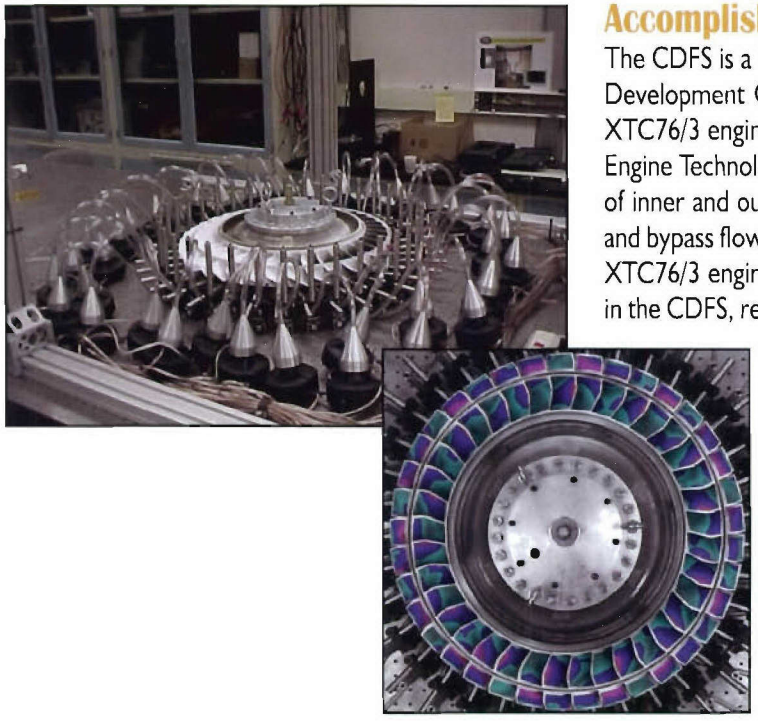
Background

The primary goal of the IHPTET program is to advance military aircraft superiority through high-performance, affordable, robust turbine engine designs. The IHPTET program has an aggressive technology plan to leapfrog technical barriers and deliver twice the propulsion capability of today's turbine engine systems. Unprecedented teaming by the Army, Navy, Air Force, National Aeronautics and Space Administration, Defense Advanced Research Projects Agency, and industry is taking place in each of the program's major technology focus areas.

AFRL Scientists Use Innovation to Achieve Results

Payoff

AFRL Propulsion Directorate scientists developed the Traveling Wave Excitation (TWE) system to simulate turbine engine rotor operational environments without the use of expensive, time-consuming, high-risk rotating tests. The TWE system successfully highlighted the dynamic behavior leading to high vibrations in the core-driven fan stage (CDFS) and provided experimental results that guided modifications of the rotor blades. Subsequent testing of the CDFS showed a significant reduction in stresses. The availability of AFRL's TWE technology provides an important experimental capability that will contribute significantly to the reliability and safety of future military turbine engines.



Accomplishment

The CDFS is a key feature in the General Electric/Allison Advanced Development Company team's variable-cycle architecture for the XTC76/3 engine, part of the Integrated High-Performance Turbine Engine Technology (IHPTET) program. The CDFS consists of rows of inner and outer airfoils separated by a solid shroud to split core and bypass flow in a single rotating stage. During initial testing of the XTC76/3 engine, large vibrations and high stresses were observed in the CDFS, requiring further investigation to mitigate risk for high-cycle fatigue, which could result in blade failures.

However, standard structural analysis techniques were not effective for understanding the behavior of the CDFS due to its unique geometry. The CDFS was tested in AFRL's Turbine Engine Fatigue facility using an innovative TWE system. Scientists developed this system in house to eliminate the need for costly and high-risk rotating tests. It simulates engine vibratory conditions in a well-controlled laboratory environment.

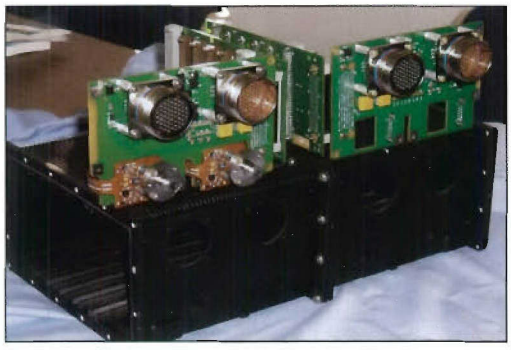
Background

AFRL developed the TWE system in its Turbine Engine Division's High-Impact Technologies in-house program. It is an important tool for in-house research efforts, as well as an ideal experimental test bed for transitioning scientific results to applied technology and development programs such as the IHPTET program. IHPTET is an aggressive technology development plan to surpass technology barriers and deliver twice the propulsion capability of today's turbine engine systems by 2005.

Advancement in Turbine Engine Controller Technology

Payoff

The AFRL Propulsion Directorate, in collaboration with Honeywell Corporation, designed a new fault-tolerant modular electronic engine control. This advancement in turbine engine electronic controllers will provide AFRL researchers with increased capability to implement and test control modes and develop engine fleet upgrades.

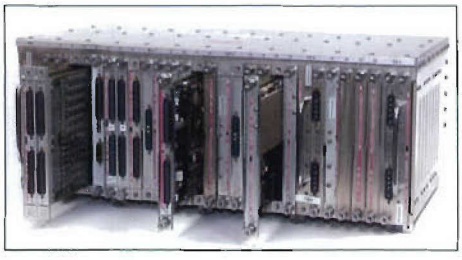


Accomplishment

AFRL's newly designed electronic engine control unit, the Modular Aerospace Controller (MAC), provides engine control researchers with the capability to simulate closed-loop performance of modern turbine engine control systems. This capability greatly simplifies the complex interfacing tasks normally associated with testing and implementing new control modes.

The MAC is capable of providing both engine control and diagnostic functions. These features will allow researchers at the AFRL's Intelligent Controls Facility at Wright-Patterson Air Force Base, Ohio, to study advanced engine control systems and health management technologies, while concurrently developing and testing new controller algorithms for upgrading fielded military engine control systems.

The MAC software programs were designed to run in a real-time operating system environment, enabling partitioning and distributed processing between modules. A unique MAC feature provides the capability to separate application and operating system software, allowing integration and use of new vendor software developments. This was not previously possible with state-of-the-art (SOA) systems.



Background

The AFRL-Honeywell MAC program was an emerging technology effort guided by the objective to develop engine control technology to advance SOA full-authority, digital engine controller systems. A primary goal of this effort was to employ common processing modules rather than dedicated circuit functions.

World-Unique Hypersonic Propulsion Test Facility Upgraded

Payoff

The AFRL Propulsion Directorate's Scramjet Research Cell 22 at Wright-Patterson Air Force Base, Ohio, was upgraded to significantly expand its test capability and enhance the accuracy of engine performance calculations. The resulting threefold increase in the accuracy of airflow measurements will substantially improve the ability to calculate critical scramjet engine performance parameters such as engine efficiency.

Accomplishment

AFRL completed a 20-week project to upgrade its Scramjet Research Cell 22, culminating in a successful scramjet operational check run. The upgrade project featured the installation of highly accurate venturi flow meters and new isolation valves to prevent unmetered air from entering the test rig.

Data collection test runs are now planned to experimentally examine an alternate pilot configuration that promises to improve the performance and operability of the baseline scramjet flow path. This world-class scramjet test facility will greatly enhance AFRL's scramjet research programs, as well as those of other government agencies and collaborating industry partners.

Background

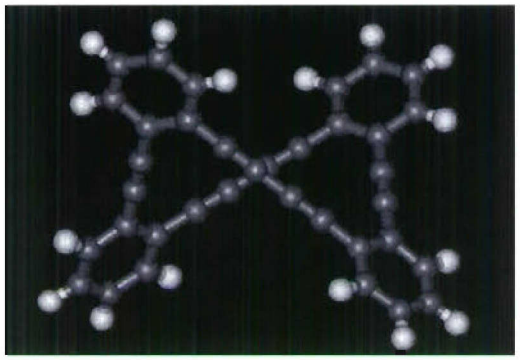
Since 1995, AFRL has been developing a modern, well-characterized, and well-documented direct-connect test facility for full-scale scramjet combustor development. Facility calibration and direct-connect combustor experiments have been under way in this facility since mid-1997.

The facility provides the Air Force the opportunity to develop and study unique concepts in supersonic combustor fuel injection, flame holding, ignition, and inlet-combustor isolation, with the ultimate goal of accelerating the development of technologies required for hydrocarbon-fueled, dual-mode scramjet propulsion systems. Potential applications for scramjet systems include rapid theater response, global-reach aircraft, and affordable access to space.

High-Energy Molecule Morphing

Payoff

Imagine the capability to simulate complex chemical formulations that will enable national defense and space adventures. Unlike the popular simulation games that are available to the general public, advanced computer capabilities enable dedicated researchers to determine the potential of future rocket fuel ingredients and even provide research chemists a pathway to their safe formulation. Researchers use advanced computational methods to model and predict several key properties of unknown chemical compounds. These methods include calculations of the electronic and molecular structures, heats of formation, vibrational spectra, and nuclear magnetic resonance chemical shifts. Reaction pathways for synthesis, combustion, and decomposition are also computed.



Accomplishment

Using computational chemistry software on supercomputers located at the Department of Defense (DoD) Major Shared Resource Centers (MSRC), the AFRL Propulsion Directorate's High-Energy-Density Matter program's theoretical chemistry researcher, Dr. Jerry Boatz, can identify new compounds at the molecular level and predict many of their properties that can be measured in the laboratory. This helps identify powerful additives or formulas that can unleash enormous energy for rocket propulsion. Researchers use these calculations to identify the most promising chemical candidates and to guide experimental efforts in synthesis and characterization.

One of the most important recent results of this scientific approach was the identification and successful synthesis of the first high-energy and stable polynitrogen ion species in more than a century. Until 1998, only two all-nitrogen species had ever been isolated in bulk quantities, but calculations showed that other polynitrogens might exist.

Background

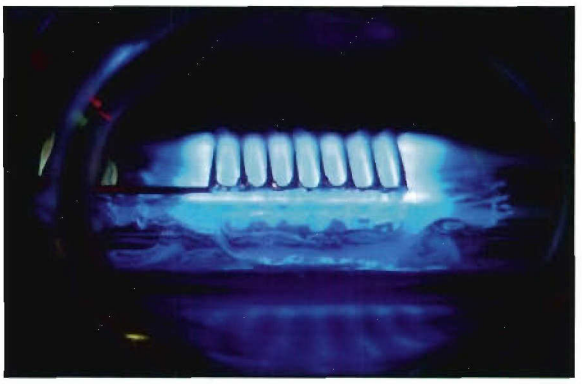
Researchers from the DoD, AFRL, academia, and industry use high-performance computers to assist in solving complex technical problems. AFRL's laboratory at Edwards Research Site uses DoD MSRC supercomputers to help design new rocket propellant ingredients for AFRL. There are four MSRCs within the DoD, each containing some of the world's most powerful computers. One of them, an IBM pSeries 690 Turbo system with over 1,400 processors (located at the Naval Oceanographic Office MSRC), is the 18th-largest computer in the world and has a peak computational speed of 6.1 trillion floating-point operations per second.

AFRL Scientists Develop Novel Atmospheric Plasma Source

Payoff

AFRL researchers created a novel plasma source that runs efficiently under atmospheric conditions and exhibits a remarkable selectivity in the manner in which energy is distributed between gas molecules and electrons. The development marks a significant advancement in the current state of the art.

Accomplishment



An AFRL plasma physics research group working with support contractor Innovative Science Solutions, Inc., developed a unique plasma source that runs under atmospheric conditions with a variety of input gases and exhibits a remarkable selectivity in the manner in which energy is distributed between gas molecules and electrons. The plasma source is a unique design, made possible by a specially designed direct current switching unit recently patented by the group.

The device is capable of switching 20 kV, with switching times as fast as 10 ns. The group is likely the first in the world to achieve such high plasma efficiencies and selectivity at atmospheric pressure. Previous researchers attempting to develop similar plasmas found excessively hot gas temperatures (1500°K and above), which precluded the use of such sources in many potential applications. This work may eventually allow some plasma processes currently restricted to vacuum chambers to be conducted in open air.

Background

AFRL conducts research, development, and transition of power technologies for use by the military services, Department of Defense agencies, and industry. The plasma switching device development was accomplished as part of the work being done by AFRL. Basic research conducted by the laboratory provides the essential foundation for technology development.

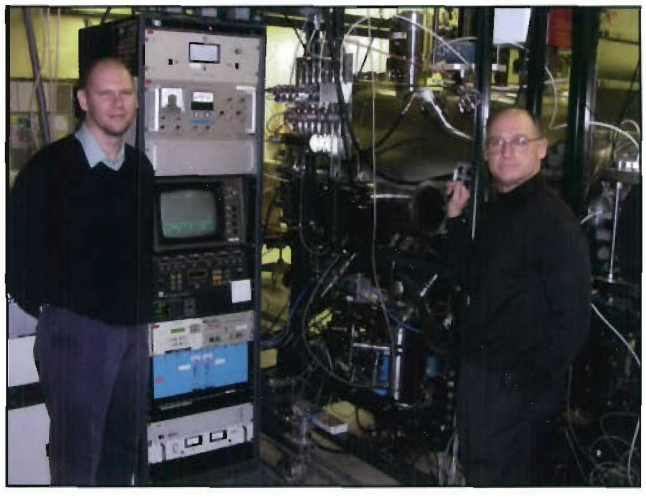
AFRL Scientists Developing High-Temperature, High-Power Capacitor Technology

Payoff

Research payoffs in AFRL have the potential to provide future capacitors the ability to withstand higher temperatures and store greater amounts of energy. AFRL scientists are developing amorphous carbon nitride (CNx) films for use as an advanced high-temperature dielectric for creating the next generation of high-temperature, high-power capacitors.

Accomplishment

CNx films are theoretically predicted to be harder than diamond and are expected to provide other characteristics similar to diamond, including high thermal conductivity, thermal stability at high operating temperatures, high electrical resistance, and high electrical breakdown strength. The high breakdown strength predicted for these materials will provide increased energy storage as compared to current equivalent-sized components, or the same energy storage of today's capacitors, but in a lighter and smaller package. This is an enabling technology needed for future applications such as the "more electric" aircraft and more portable electric rail weapon systems, and for a large number of current applications that will benefit from greater durability and mean time between failure.



Background

AFRL conducts research, development, and transition of power technologies for use by the military services, Department of Defense agencies, and industry. AFRL developed the CNx films for use as a capacitor dielectric. Basic research conducted by the laboratory provides the essential foundation for technology development and systems acquisition.

Affordable Machining Program Targets Cost Reductions In Aerospace Components

Payoff

Materials and Manufacturing Directorate scientists and engineers, in a collaborative effort with researchers from industry and major universities, made significant advancements in the development of analytical tools and advanced machining technologies for aerospace components. Since machined products primarily come from a supplier base, benefits will be realized through reduced prices and shorter delivery times.

Technology innovations and insights realized under the Affordable Machining Program (AMP) effort are applicable wherever metallic structural components, turbine blades, and actuators are used.

Accomplishment

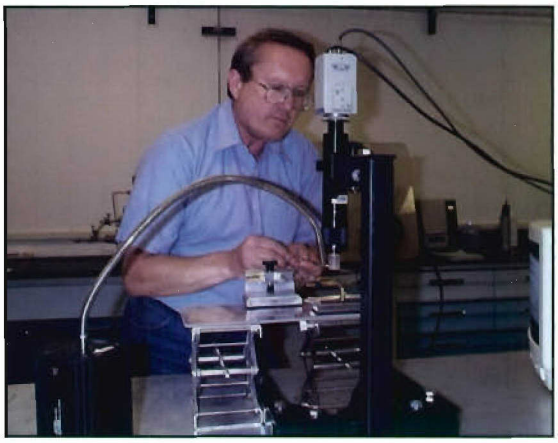
The AMP addresses customer needs by providing low-cost, high-quality machined parts for aircraft components. Working together under AMP, the team dramatically improved the parts quality of the F-15's vertical tail leading edge and wingtip using state-of-the-art, high-speed machining techniques and stable cutting parameters, and by replacing the forged material stock used to build these components with stress-relieved plate stock. These innovations result in a calculated $16 million cost savings for the Air Force.

Tangible benefits include reduced machining time, scrap and rework rates, and tooling and assembly fixtures, along with increased part accuracy and quality. Intangible benefits include more complex machined-component designs for increased affordability (through parts unitization) and reduced inventory.

Background

The purpose of AMP is to develop and implement analytical tools and advanced machining technologies to enable lower-cost fabrication of machined aerospace components. AMP is a cost-shared program funded by the Metals Affordability Initiative and industry. Primary team members include AFRL, Boeing, Carpenter Technology, Northrop Grumman, and Rolls-Royce. The subcontractors include Cincinnati Machine, TechSolve, Third Wave Systems, Vykor, the University of North Carolina at Charlotte, the University of Florida, and Washington University.

Because the team is focusing on existing and pervasive wrought material forms such as plate, bar, and forgings, additional time and expense to certify components is not necessary. Their proposed technologies will also reduce the time to market for machining modifications by increasing confidence in the process before it hits the shop floor. This, in turn, will reduce first article lead times by providing improved first-time quality and lower production lead times by increasing reliability and accuracy. The participation of material suppliers and the machine tool industry in the program further enhances pervasiveness. These entities have the incentive to provide the technology to as many producers as possible. In addition, the technology partnership is involved in a range of applications to further distribute the technology throughout industry.



Proximity Transmitter Interference Limiting Technique

Payoff

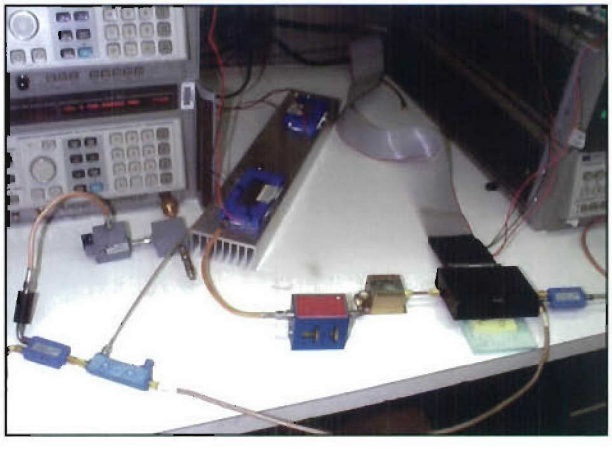
The AFRL Sensors Directorate, through in-house research, designed a more efficient, cost-effective technique to limit transmitter signal interference in environments where multiple receivers and transmitters are present. The benefit of this new technique is the ability to suppress noise and/or extraneous signals that can prohibit a critical signal from being received and interpreted. Suppression can be completed without the need to access a sample of the transmitter signal at its source.

Accomplishment

The new technique provides a low-complexity, reduced-cost, large signal interference suppression capability for receivers colocated near transmitters on a common platform. The invention is an analog solution to a difficult problem in which a digital equivalent does not exist. The ability to detect weak signals from a clutter of stronger signals is critical to many sensor platforms and detection operations.

Background

Cosite interference is a serious problem in detecting low-level signals, since many platforms have multiple transmitters in proximity. AFRL's observation led to the investigation of the current techniques used to suppress extraneous signals and noise.



Conventional techniques for providing continuous wave signal interference mitigation between a common platform radio frequency transmitter and receiver involves installing signal couplers in the transmission path between the transmitter and the transmitting antenna. The couplers obtain a copy of a strong receiver-interfering transmitter signal for use in a signal subtraction or cancellation arrangement. This leads to the cancellation of the offending signal. This technique requires a significant amount of host platform characterization to be performed to install the signal suppression architectures.

The present invention provides active interference signal cancellation protection for a low-level receiver operation near a transmitter antenna and provides this protection with a nonlinear ferrite element without the need to access a sample of the transmitter signal at its source. The present invention allows a given receiver to maintain its sensitivity in the presence of a colocated transmitter operating simultaneously.

New Algorithms Improve GPS Signal Acquisition

Payoff

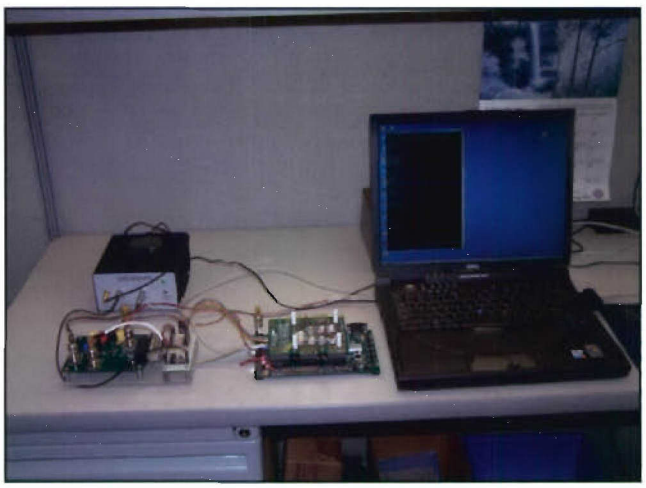
Scientists devised a new method to correlate more efficiently the Global Positioning System (GPS) signal acquisition. This new software approach will greatly accelerate up the code and frequency acquisition of the GPS receiver.

Accomplishment

Scientists at the AFRL Sensors Directorate improved the GPS satellite signal acquisition method and device. They reduced the number of operations in the block correlation used to determine Doppler frequency and GPS codes. Reducing the number of operations in block correlations increases acquisition speed and reduces energy requirements.

Background

GPS is a critical enabler for many commercial and military systems, but GPS satellite signals are easily jammed or lost due to terrain masking, maneuvering, or multipath. A software receiver implementation offers significant advantages to the user in terms of system programmability and robustness. The computational complexity of receiver functions must be reduced in order for receiver functions to be implemented affordably in software.



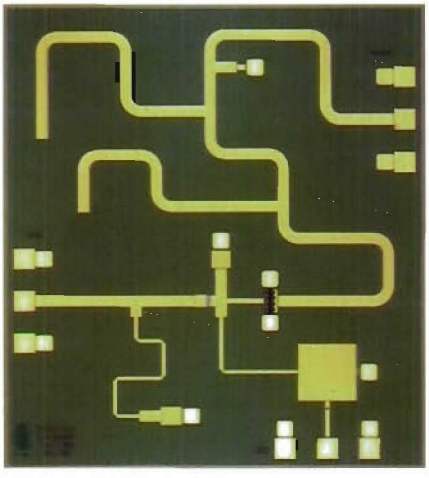
Acquisition of the GPS satellite signal is a key receiver function that is computationally complex and prohibitively expensive to implement in real-time software possessing current technology. This invention reduces the complexity of GPS code acquisition, allowing the acquisition function to be implemented in the software.

To acquire the GPS signal, the received signal must be correlated with a replica of the code division multiple access code generated in the receiver. Traditional correlation methods use continuous sliding multiplication and addition to align the phase of the signal and replica code. The approach taken for this invention down-converts the sampled data to base band, partitions the sampled data into small blocks, performs frequency domain correlation in block level, and coherently combines the block-level results through fast Fourier transform, greatly reducing the total computation time.

AFRL Scientists Design Innovative, Highly Efficient Power Amplifier

Payoff

The AFRL Sensors Directorate design team combined a state-of-the-art transistor technology with a novel circuit implementation technique that culminated in a significant advancement in monolithic microwave integrated circuit technology. This accomplishment will have far-reaching implications for vital aerospace applications.



Accomplishment

AFRL scientists developed a solid-state power amplifier yielding the highest reported power-added efficiency performance and the widest bandwidth for a Class E amplifier at X band. Based on the indium phosphide (InP) double heterojunction bipolar transistor (DHBT) technology, the Class E amplifier achieved 65% power-added efficiency, 100 mW output power, and 11 dB gain with 20% bandwidth.

The Class E amplifier represents the first implementation of an ultra-high-efficiency monolithic microwave integrated circuit at X band. This device provides low-offset voltage, low-knee voltage, high-breakdown voltage, and high-cutoff frequency, making the InP DHBT an attractive technology for high-efficiency and high-frequency performance.

Background

Modern space-based radar systems place new requirements on radio frequency power amplifiers because of the desire to reduce system size, weight, and launch cost. The major shift in amplifier specifications focuses more on circuit efficiency to reduce prime power requirements and improve system reliability due to lower power dissipation. In addition, broadband high-efficiency circuits will enable enhanced system capability.

Switch mode amplifier design, such as that of the Class E power amplifier, can potentially achieve 100% drain or collector efficiency when driven into saturation. However, due to device limitations, most demonstrations of Class E amplifiers have resulted in low radio frequency or limited bandwidth.

MEMS Switch Encapsulation and Sealing Process Developed

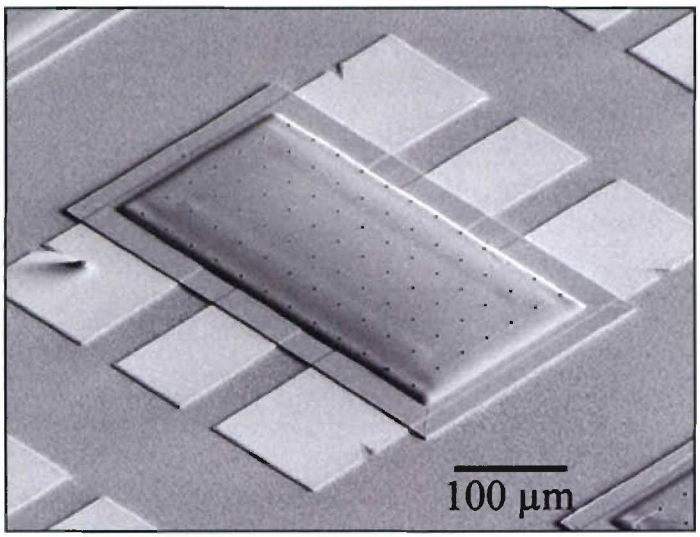
Payoff

AFRL scientists developed a process to package radio frequency (RF) microelectromechanical systems (MEMS) switches within a conformal dielectric shell. The demonstration of the wafer-level encapsulation process for RF MEMS switches will promote insertion of MEMS switches into communication and radar applications for military, as well as civilian, applications. The process, compatible with both capacitive and metal-contact switches, provides a low-loss, low-cost packaging approach to protect the switches from external contamination.

Accomplishment

The AFRL Sensors Directorate scientists developed a wafer-level encapsulation process for RF MEMS switches. On-wafer encapsulation is a conformal process that seals the RF MEMS switches within a dielectric shell as part of the fabrication process, thereby simplifying the production process from a mechanical and cost standpoint.

Innovations include process integration, film selection, and adhesion through shell release and sealing. On-wafer encapsulation thereby creates a low-profile, small-area footprint package, which protects the switch while minimizing handling issues. Switch packaging is a critical issue for technology insertion. A successful packaging approach is critical for insertion of MEMS switches into system demonstrations, including novel radar system designs.



Background

RF MEMS switches cannot be operated outside a controlled laboratory environment without a package that provides protection from dust, moisture, and handling. The demonstrated encapsulation process is a clean-room process that minimizes external contamination of the devices and provides protection from additional handling. Following switch fabrication, a dielectric shell with access holes is deposited over the switch, the switch is released using a wet process, and the shell access holes are sealed.

RF MEMS switches are an enabling technology for many military and commercial applications. The switches offer unprecedented electrical performance improvements over conventional semiconductor devices. The primary metrics for comparison are insertion loss and DC power consumption. PIN diodes exhibit insertion losses of ~ 1.0 dB and consume ~ 50 mW DC power for switching. RF MEMS switches exhibit insertion losses of ~ 0.1 dB and consume < 0.1 mW DC power. These improvements of low switch loss and low power requirements enable dramatically improved designs of communication and radar systems.

The selective nature of the encapsulation process allows for easy integration of the switches into circuits such as phase shifters or tunable filters. Alternative approaches require high-temperature and/or high-voltage processes and result in a higher-profile, large-area footprint package.

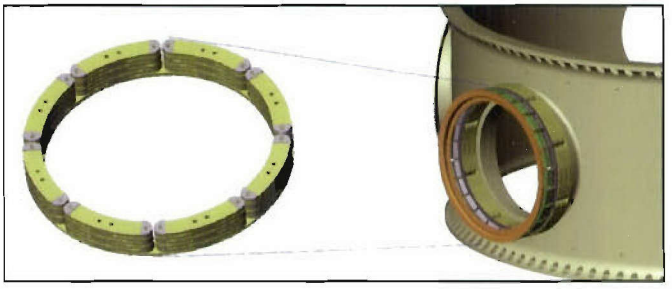
Shock Ring Technology Impacts Future Spacecraft Programs

Payoff

Shock ring technology will increase the number of low-cost payload launch opportunities, which will have a tremendous impact on future spacecraft programs. This increase is anticipated due to a reduction in expensive payload design and redesign costs. Additionally, integration with a low-shock separation system will further reduce integration and testing requirements.

Accomplishment

The AFRL Space Vehicles Directorate, along with the Space and Missile Systems Center's Detachment 12 and CSA Engineering, Inc., developed a shock ring system under a Small Business Innovation Research Phase II contract aimed at creating a whole-spacecraft passive shock isolation system for a variety of launch vehicles. The shock ring first flew on the Vibro-Acoustic Launch Protection Experiment-1 (VALPE-1) aboard a Terrier-Orion sounding rocket and served as the passive stage for an active-passive hybrid system aboard VALPE-2.



The shock ring system can attenuate the harsh shock environment for a multitude of launch vehicles, including the evolved expendable launch vehicle (EELV), in combination with the EELV secondary payload adapter and Missile Defense Agency (MDA) target launch vehicles. This technology has generated interest from the Air Force, Department of Defense, commercial companies, and universities to enable the flight of many delicate payloads.

Currently, to compensate for harsh launch environments, payloads must be designed and tested to very high shock and vibration levels, greatly increasing the mass and cost of many payload components. The shock ring reduces these high costs by allowing more satellites to be launched or more capability with a given payload weight. The advantage of a shock ring system over previously flown isolation systems is that the shock ring is not a point design for a given launch vehicle payload combination. It is a one-or-two-sizes-fit-all approach.

Background

Shock ring systems are mounted between the primary spacecraft separation system and the launch vehicle. For MDA target launch vehicles, the ring can be attached as a wafer between a motor, such as the M57, and an upper stage, where it attenuates high-frequency loads while replicating the existing bolt interface for the existing attachment points. For other launch vehicles, the shock ring attaches between the separation system and the launch vehicle. To provide minimal impact to the launch vehicle, the shock ring duplicates the standard bolt pattern of the vehicle and separation system and can be inserted with only 2 or 3 in. of additional height.

The first operational flight will be on the Multiple Space Vehicle-05 mission, launched on an Atlas V carrying FalconSat-3, a US Air Force Academy satellite. The flight will demonstrate the effectiveness of the shock ring system for a host of large launch vehicle applications.

Elastic Memory Composite Hinge

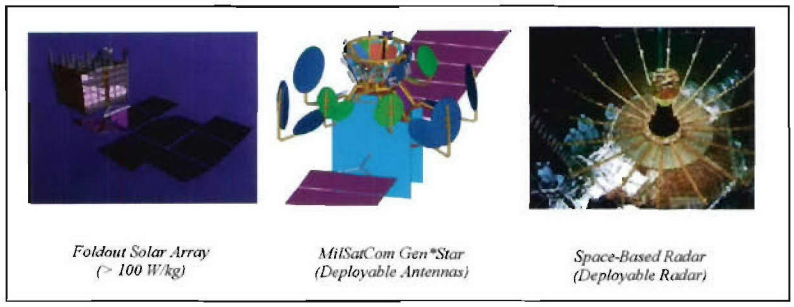
Payoff

Engineers from the AFRL Space Vehicles Directorate and Composite Technology Development, Inc. (CTD), of Lafayette, Colorado, developed technology that has one-fifth the mass, twice the strain capability, and 10 times the damping characteristics of conventional hinge technology. Researchers need large sensor systems and solar panels for space-based surveillance. Due to their size (>10 meters), such systems have deployable structural components. Mechanical deployment systems have up to 75% of their mass at the joints (hinges and latches).

Accomplishment

Engineers from AFRL and CTD developed elastic memory composite (EMC) hinges. EMC is a fully cured fiber-reinforced composite consisting of traditional fiber reinforcements, such as graphite or glass, and a special "elastic memory" polymer matrix developed by CTD.

This novel composite can be folded into a very compact shape and deployed in space upon heating. Hinges made with EMC can be used to stow and deploy large sensors in space. A specific thermomechanical cycle allows EMC materials to achieve, store, and recover relatively high packaging strains.



Foldout Solar Array (> 100 W/kg)

*MilSatCom Gen*Star (Deployable Antennas)*

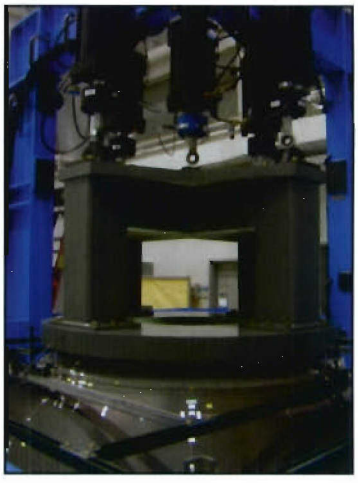
Space-Based Radar (Deployable Radar)

Researchers induce initial strains by applying a load that forcibly folds the EMC material into the desired, packaged shape while at an elevated temperature above the polymer's glass transition temperature (Tg). Once this has occurred, the packaged EMC material will hold the constrained shape indefinitely. To deploy, the EMC material is again reheated to an elevated temperature above Tg.

Background

The Department of Defense Space Experiments Review Board approved a space shuttle flight experiment with EMC hinges to help transition the technology to the satellite primes. The goal of this experiment is to determine the accuracy and the stability of deployment in the space environment. Researchers baselined a 4-meter deployable boom for the FalconSat-3 flight. They are also pursuing insertion into other large deployable experiments, such as the Innovative Space-Based Radar Antenna Technology program.

EELV All-Composite Joint Payload Attachment Fitting



Payoff

Boeing Delta IV Payload Accommodations and Alliant Techsystems (ATK) developed technology under the AFRL Space Vehicles Directorate's sponsorship. The technology was used to demonstrate automated production on an all-composite forward flange for the Boeing-developed 1780 mm payload attachment fitting for evolved expendable launch vehicles (EELV) and commercial launches. The technology reduces manufacturing costs and mass while maintaining much-better-than-required strength and stiffness.

Accomplishment

Engineers from AFRL, Boeing, and ATK completed production of a qualification test and cyclic test structure to evaluate the design-critical, all-composite flange detail. The testing successfully qualified the flange to 125% of design load, followed by cyclic testing qualification to 175% of the design load. The joint never gave any indication of distress.

The result of an evolutionary process involving multiple manufacturing and analysis cycles, the design uses Z-pinning (through-thickness fiber reinforcement) technology and composite/foam transitions to control strains and maintain high structure toughness at the high-load attachment points. The forward flange of this test structure was fabricated almost entirely by computer tow-placement methods. Only Z-pins were installed manually. The resulting design will provide a prototype for gradual replacement of most aluminum flanges on launch vehicles with lower-cost composite designs.

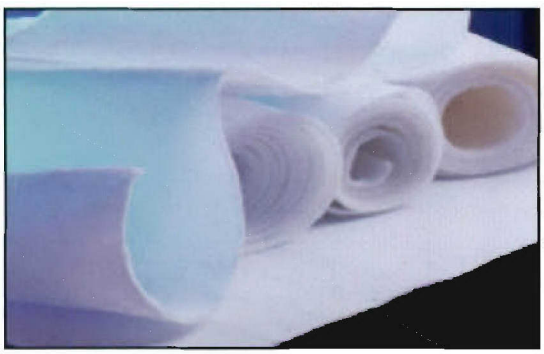
Background

During the past 20 years, large structural composite adapters and fairings have been gradually introduced to replace heavier aluminum structures. One feature was held over from the earlier all-aluminum designs—the aluminum connections. The aluminum connections provide high ductility and toughness absent until now from many composite structures. The difficulties linked to the use of the aluminum joint are the labor required to install the flanges during composite fabrication (high touch labor) and the added attention needed to overcome thermal mismatch of these materials during curing.

Ultralightweight Aerogel-Based Thermal Insulation

Payoff

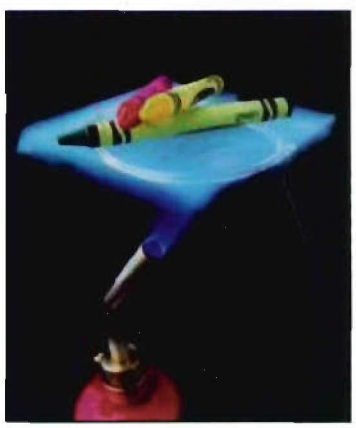
The AFRL Space Vehicles Directorate and Aspen Aerogels, Inc., developed and demonstrated an ultra-low-density aerogel-based thermal insulation, designed to replace multilayer insulation (MLI) for a variety of space missions, such as the Space Tracking & Surveillance System (STSS). Raytheon Space and Airborne Systems Company sees this new insulation technology as one of the keys to overcoming thermal challenges facing future STSS payload designs and avoiding some of the thermal modeling problems that have delayed the current generation of sensor payloads.



Accomplishment

Under AFRL's sponsorship, Aspen Aerogels developed a cost-effective, ultralightweight aerogel-based thermal insulation. The optimization of the formulation and process variables led to the successful demonstration of the ultralightweight (2-4 lbs per cu ft) insulation. The thermal conductivity in vacuum (10-3 torr) of the materials fabricated is around 1 mW/m-K (milliwatt per meter-Kelvin) at 160°C (the maximum temperature expected for exposure to Solar Albedo in low earth orbit [LEO]). This corresponds to a thermal resistance value of better than R-140/in. thermal resistance in the most challenging LEO environmental conditions.

With its thermal conductivity of R-15/in. at ambient terrestrial conditions and R-140/in.+ under LEO conditions, the flexible aerogel ranks significantly better than all other high-performance insulations. As a replacement for MLI, the flexible aerogel blanket offers equivalent thermal performance in vacuum; significantly better thermal performance in atmosphere; faster off-gassing rates; and dramatic improvements in integration time, touch labor and, ultimately, system cost.



Since the insulation material is a solid versus a series of interlaced blankets, as with MLI, the aerogel insulation technology promises to be far more reliable in terms of thermal insulation performance delivered, repeatability, and ability to accurately model a system's thermal performance. The aerogel blanket is not sensitive to thermal shorting by compression, a common failure mode for MLI. MLI typically is good for two installations before compression compromises the system irreversibly.

Background

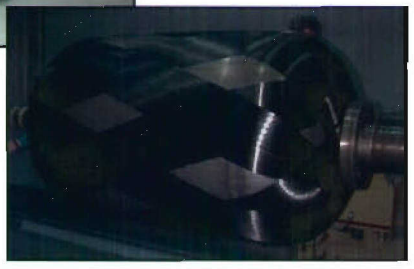
Parasitic heat leaks on cryotelescope platforms degrade sensitivity and mission performance. Once validated for STSS, the aerogel insulation technology will be directly applicable to a number of other US military systems, such as the exo-atmospheric kill vehicle on the ground-based midcourse interceptor, as well as the high-altitude airship and the airborne laser. Virtually any US space platform requiring thermal management will benefit from the successful development of the aerogel insulation system.

Cryogenic Composite Fuel Tanks

Payoff

Current work at the AFRL Space Vehicles Directorate is focusing on the successful development of an all-composite cryogenic fuel tank to be used in a wide array of systems. Benefits of this technology will be felt on the ground, in the skies, and in the far reaches of space.

Manufacturing and design techniques developed in joint work with contractors have led to successful testing of several all-composite designs. Innovations derived from the petrochemical industry and inspirations from biological systems such as self-healing composite materials will provide the advances in technology required to make composite tanks feasible for next-generation Department of Defense systems.



Accomplishment

AFRL engineers and various small business contractors developed composite technologies that will reduce the weight of fuel tanks by up to 60%. These technologies range from self-healing composites to prestressed composite plumbing for systems. These systems also have the added benefit of reduced cost and increased strength over conventional materials.

Researchers worked to provide improved composite and resin systems, innovative manufacturing techniques, and novel curing processes. These efforts aimed at improving composite materials and mitigating microcracking of these materials.

Background

For many years, composite materials have shown great promise as a structural material because of their high strength-to-weight ratio. Many technologies have benefited because of this material, but advances in space vehicles have been limited in one particular area because of a single problem. Cryogenic temperatures like those encountered when storing rocket fuels have led to tank failure due to microcracking of the tank walls. The X-33 program was a highly publicized example of this exact problem. In recent years, researchers have made great advances in both understanding and conquering this phenomena.

Minotaur Advanced Grid-Stiffened Composite Fairing

Payoff

Technology developed at the AFRL Space Vehicles Directorate was used to demonstrate production of a grid-stiffened composite payload fairing. Researchers used this nearly autonomous process to fabricate the first grid-stiffened composite fairing ever used on a production launch vehicle. This technology resulted in a design that has twice the payload volume and no significant weight penalty over traditional launch vehicle fairings.

Accomplishment

Engineers from AFRL and Boeing Phantom Works completed production of a qualification test and the first flight for the Orbital/Suborbital program/Minotaur advanced grid-stiffened (AGS) payload fairing. The resulting structure was load tested and flight qualified. System-level tests of acoustic mitigation and radio frequency mitigation have also been easily met for the first mission.

This nearly autonomous manufacturing method utilizes a combination of advanced fiber placement technology and innovative tooling to allow large composite structures to be fabricated at a lower cost than previously possible. This technique also provides a great deal of flexibility in structural design, allowing last-minute structural modifications to be made during fabrication.

Background

From 1985–1993, the US and Russian governments spent millions on AGS research without achieving a viable manufacturing technique or flight-quality structure. AFRL's Advanced Composite Shroud program was the first program that successfully developed robust AGS structures and designs that led to a flight demonstration on the Missile Defense Agency's Combined Experiments program. The AGS technology was demonstrated on the Minotaur launch vehicle and will be integrated into a first launch supporting the first near-field infrared experiment.

The manufacturing and design techniques developed in this program dramatically reduce the cost of fabricating launch vehicle fairings and other structural components. Engineers achieved this cost reduction by eliminating the large amount of manual labor associated with placing honeycomb sandwich in traditional composite sandwich structures. This benefit occurs without any loss in structural performance and with the added benefit of increased design and manufacturing flexibility.

Silicon Lightweight Mirrors Developed for High-Energy Laser and Aerospace Systems

Payoff

The AFRL Space Vehicles Directorate awarded a Phase I and II Small Business Innovation Research (SBIR) contract to Schafer Corporation, of Chelmsford, Maryland, to develop silicon lightweight mirrors (SLMS™) technology for aerospace and industrial applications. This development will improve the performance of high-energy laser systems, while providing improved, lightweight, athermal mirrors for space and airborne optical systems.

Accomplishment

Under the SBIR contract, Schafer Corporation successfully manufactured high-performance silicon and silicon carbide foam-core lightweight mirrors up to 13 cm in diameter, and is working on manufacturing mirrors up to 56 cm in diameter. Since larger mirrors have a much broader range of applications, Schafer plans to scale SLMS mirrors from 0.5 to 1.5 meters during the next 2 years.

A second significant impact of SLMS technology is the athermal characteristic of these mirrors. The silicon surface of the mirror can be easily polished to a surface figure of 0.02 waves per RMS at 633 nm at room temperature and will hold that surface figure while operating at temperatures as low as 27°K. This means these lightweight mirrors are easier to manufacture for low-temperature applications and do not have to be actively cooled to prevent distortion, further reducing the weight of the aerospace system transporting the mirror.

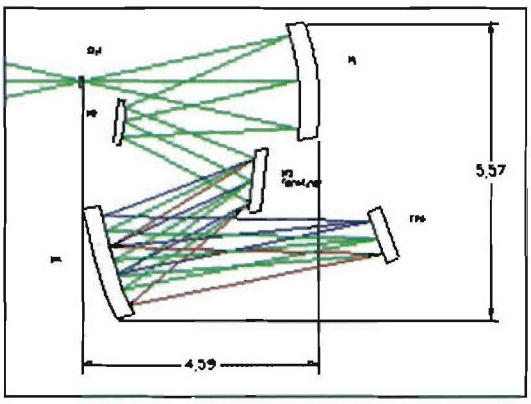
Background

SLMS mirrors are extremely lightweight, less than 10 kg per m^2, and very stiff, with a first mode frequency much greater than 500 Hz. These characteristics will serve to lower the weight of high-energy laser systems because both the mirrors and the support structure will be lighter than current systems. Schaefer Corporation's partnership with AFRL has enabled them to build and demonstrate mirrors tailored for Department of Defense applications.

Revolutionary Approach Used for Dual-Octave Spectral Imagery

Payoff

Using a revolutionary approach, AFRL Space Vehicles Directorate researchers concluded a laboratory demonstration for dual-octave hyperspectral imagery in a compact cryogenic package. This new approach represents a simplification and mass reduction over traditional approaches involving multiple focal plane arrays (FPA), dispersing elements, and optical beam splitters. The new approach is significant for space-based hyperspectral imagers operating in the infrared. There will be noteworthy savings with the cryocooling requirements and launch costs associated with such midwave infrared (MWIR) and long-wave infrared (LWIR) hyperspectral imagery.



Accomplishment

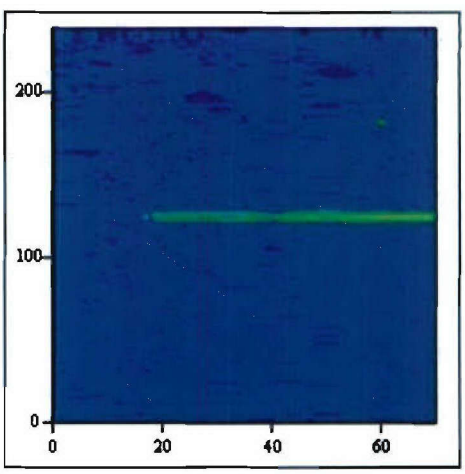
AFRL's new approach overlaps grating orders and focuses them onto a dual-waveband, infrared FPA, creating spectral images of a scene simultaneously over a broad range of infrared wavelengths. The resulting spectral imagery is obtained with high signal to noise, since the grating is operating near peak blaze efficiency over the full wavelength range, with only a single grating element and FPA.

Equally important, the registration of the spectral images is perfect, with no corrections needed for pixel misalignments between channels. The results of a ground-based demonstration in the MWIR and LWIR were prepared for the International Society for Opitcal Engineering's *Optical Engineering* journal.

Background

Dualband, infrared FPAs were originally developed for imaging applications, as they were desirable for simultaneous viewing of the target in separate, spatially collated wavebands. An AFRL patent later described improvements in hyperspectral imaging capabilities made possible with these dualband FPAs.

A demonstration of the concept requires sophisticated subassemblies, including infrared foreoptics that image over a wide range of wavelengths, a spectrometer module in the form of an optical bench that is cryogenically cooled for suppressed thermal emission, the dualband FPA and its drive and data acquisition electronics, and a cryogenic Dewar to enclose the cooled components of the assembly. Although complex, the demonstration was deemed necessary to validate initial assumptions, including the efficiency of the grating used in two contiguous grating orders at cryogenic temperatures and the capability of the dualband FPA and grating combination to maintain high levels of spectral purity for the spectra generated in the two orders.



Breakthroughs Realized in HAARP

Payoff

Experiments at the AFRL Space Vehicles Directorate's Gakona Research Facility in Alaska produced breakthroughs in artificial generation of optical emissions in the ionosphere by high-power radio waves. The facility, operated by the High-Frequency Active Auroral Research Program (HAARP), is currently under construction to complete a planned 3.6 MW high-frequency transmission capability. Nevertheless, it has already proven that it is a unique research instrument to exploit emerging ionosphere/high-power radio technology for next-generation, space system concepts and operations.

Accomplishment

A key feature of the HAARP array utilized for the first time is the ability to transmit at the second harmonic of the electron gyrofrequency near 2.8 MHz. This gyroharmonic resonance provides a critical test of theories related to the space plasma processes that can be triggered via interactions with high-power radio waves. Although the radio waves produced at 2.8 MHz are far weaker than those at higher frequencies, where the array has much better gain, spectacular levels of artificial airglow were observed when the transmitter was tuned to the second gyroharmonic frequency.

Unexpectedly bright airglow was also observed when the experiments were repeated at the third gyroharmonic frequency, where previous experimenters reported a decrease in effects. Another major result was obtained during an attempt to artificially modulate a pulsating natural aurora. This experiment generated small speckles, superimposed on the aurora, that turned on and off in conjunction with the HAARP transmissions.

Initial analysis shows that the speckles are orders of magnitude brighter than optical emissions produced at any high-frequency facility, bright enough to be seen with the naked eye, and probably result from excitation of particles in the layer of the ionosphere near 100 km altitude. This is a watershed development in triggering processes in the space environment, where artificially induced effects are now becoming comparable in magnitude to natural features, such as the aurora, and can be detected and observed without the aid of sensitive instrumentation.

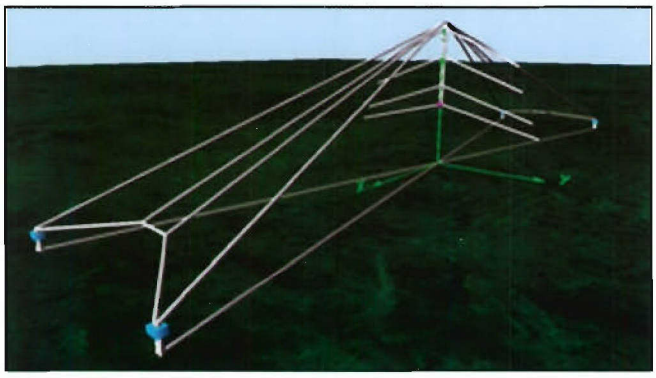
Background

In addition to researchers from AFRL and the Naval Research Laboratory, who manage the HAARP program, participants included scientists and students from Cornell University, Geospace Research, Inc., Stanford University, the University of Alaska at Fairbanks, the University of California at Los Angeles, Utah State University, and several other institutions.

DISS Performance Upgrade Via Genetic Optimization

Payoff

An AFRL team of engineers applied genetic optimization to modify the Digital Ionospheric Sounding System (DISS) antenna, resulting in 10 times the transmission performance. This modification will eventually increase data quality at 14 global sensors and will deploy for a fraction of the cost of a complete antenna replacement.



Accomplishment

A joint team of engineers from the AFRL Space Vehicles and Sensors Directorate's used genetic optimization to "evolve" a strategically placed set of additional wires on the existing off-the-shelf antenna selected as the DISS antenna. The off-the-shelf antenna the Air Force selected was not well suited for the task of ionospheric measurements.

The original DISS antenna exhibited loss in transmitted power across many of the radio frequencies critical for ionospheric measurements. By using genetic optimization, the team of engineers was able to correct the problem inexpensively and efficiently while considering critical parameters such as safety, ease of installation, and mechanical stability in addition to transmitted power performance.

Background

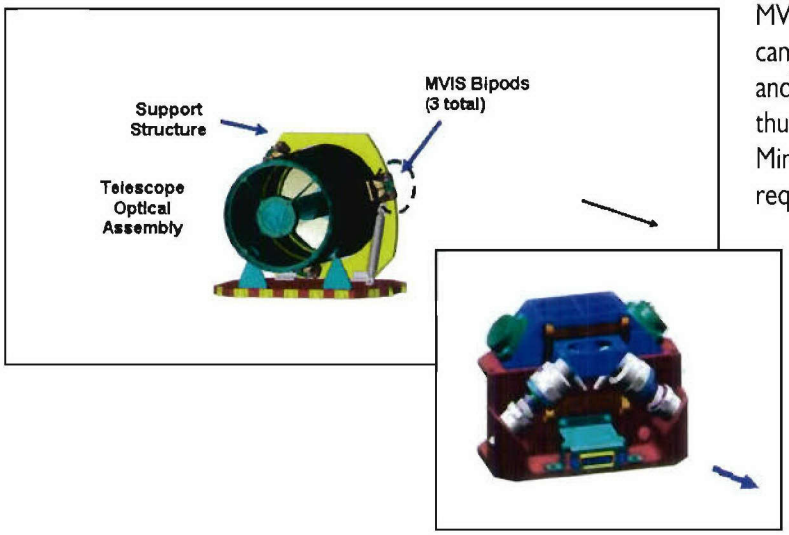
The US Air Force Weather Agency and AFRL operate the DISS network in order to observe the global ionosphere in real time. The network provides abundant product data including specification and forecasts of high-frequency radio propagation, ionospheric electron density, total electron content, and ionospheric-induced scintillation of electromagnetic waves.

Genetic algorithms use nature's evolution process as a basis for selecting the optimal solution to a complicated problem of many parameters. AFRL is researching the use of genetic algorithms to optimize the parameters of existing antenna designs. This project provided a perfect opportunity to combine the expertise of two AFRL directorates in transitioning the AFRL Air Force Office of Scientific Research–sponsored research into the field.

MVIS Developed For On-Orbit Active and Passive Vibration Isolation

Payoff

Honeywell, under the direction of the AFRL as part of a Technology Investment Agreement, is developing a miniaturized vibration isolation system (MVIS). The MVIS will be used to provide on-orbit active and passive vibration isolation for the optical assembly on the TacSat-2 Imager Payload telescope. This technology results in a low-profile platform with reduced mass and power requirements over conventional systems. Technology benefits to be gained include improved imaging/ targeting resolution, low-profile and modular retrofit capability, and >20 dB reduction of vibration transmission over a broad frequency range.



Accomplishment

MVIS isolates sensitive components, such as a camera, from the vibration environment of a satellite and suppresses vibrations on the platform itself, thus increasing imaging or targeting resolution. Miniaturization reduces weight, volume, and power requirements. The small size also opens up the possibility of using the system as a retrofit solution if sensor vibration problems are discovered late in the design cycle. MVIS is scalable to optical surveillance imaging requiring nanoradian accuracy with improved accelerometers.

MVIS will isolate the TacSat-2 Imager Payload telescope optical assembly from on-orbit spacecraft bus disturbances. The system consists of three bipods mounted at each 120° location around the circumference of the imager payload. Each bipod contains two hybrid isolators, each consisting of a passive isolator, which provides passive isolation through its spring stiffness and damping, and an active piezoelectric stack in series, which strains under voltage to provide active mechanical motion.

Launch locks will hold the platform firmly in place during launch and will be released once on orbit. A system of accelerometers and load cells provides MVIS with the information needed to support the active portion of the isolation, and power electronics and control system hardware provide the control signals to each strut.

Background

Planned surveillance missions such as space-based radar have unprecedented requirements dictating submicron- or nanometer-level structural stability and pointing accuracy. The resolution of a sensor on orbit is directly limited by the stability of the platform on which it is mounted. Satellites have many sources of vibration jitter during operation that may disrupt a sensor platform, such as control moment gyros on the bus or cryocooler vibrations on the platform itself, requiring an isolation system to isolate the platform from these disturbances.

State-of-the-art on-orbit vibration isolation systems consist of active and passive stages, with the active portion required to gain performance at the lower frequencies. MVIS will evaluate the ability of a miniaturized vibration isolation system to isolate a platform on a spacecraft from spacecraft jitter, proving the technology in a realistic environment, but at miniature size.

A Modular Satellite Bus Architecture To Enable Rapid Construction and On-Orbit Servicing

Payoff

Under an AFRL Small Business Innovation Research (SBIR) Phase II contract, AeroAstro, Inc., is developing SpaceFrame, a modular satellite bus architecture to enable rapid configuration and on-orbit servicing. AeroAstro's modular SpaceFrame technology provides a means to develop highly reliable small satellites quickly at a significantly lower cost. This inexpensive modular structure can be populated with a variety of payloads and support equipment, with quick turnaround times. AeroAstro envisions using the SpaceFrame technology on virtually all its future satellite development efforts, benefiting both commercial and military customers.

Accomplishment

The AFRL-funded Phase II SBIR development effort was focused on the detailed design and analysis of the SpaceFrame bus concept, followed by the fabrication and test of an engineering design model. AeroAstro applied the SpaceFrame design architecture to the Department of Defense Space Test Program Satellite-1 (STPSat-1) spacecraft to facilitate and expedite satellite integration, and to ensure that STPSat-1 is compatible with the structural and volumetric manifest requirements of the Delta IV Evolved Expendable Launch Vehicle Secondary Payload Adapter (ESPA).

While the SpaceFrame design can be configured to be compatible with a variety of launch vehicles, AFRL and AeroAstro believe that tailoring the design to be ESPA compatible provides the most value to the military and commercial space community. The ultimate goal of this modular bus development effort is to significantly reduce the design and assembly timelines for a satellite system, while also facilitating low-cost manifest opportunities for small satellite space missions.

Background

The current platform concept incorporates a flexible modular design capable of supporting a wide range of missions. These platforms are engineered to allow a small satellite user to choose from a set of flight-proven technologies and to rapidly configure a satellite with drastically reduced system trade-offs, integration, component testing costs, and schedule timelines. The modular design meets the need for satellites to be readily adapted to accommodate different payloads and mission objectives, rapidly and at low cost. The SpaceFrame concept is being proposed for several spacecraft opportunities.

Technology Transfer

Page

Continued on next page

AFRL Laser Hair Removal Research Helps Patients With PFB

Payoff

Pseudofolliculitis barbae (PFB) is hard to pronounce, but for those forced to shave their curly, coarse facial hair, it is even harder to live with. This was the case until some groundbreaking laser hair removal research, managed by the AFRL Air Force Office of Scientific Research (AFOSR) for the Department of Defense-funded Medical Free Electron Laser (MFEL) program, led to an important discovery.

The MFEL program explores the application of pulsed lasers and other optical technologies to combat casualty care and military operational medicine. The program stimulated the original studies and uses of pulsed lasers in medicine and surgery and led to the development of more than 30 Food and Drug Administration-approved clinical procedures.

Accomplishment

AFRL AFOSR's Physics and Electronics program manager, Dr. Howard Schlossberg, managed the research leading to laser hair removal, which was supported by the MFEL program. Approximately 10 years ago, Dr. Rox Richard Anderson, an AFRL AFOSR-sponsored scientist and associate professor of dermatology at Harvard University, invented and developed laser hair removal by using optical pulses to target melanin pigment in hair follicles. A former colleague and Navy doctor, Captain E. Victor Ross, based in San Diego, California, used Dr. Anderson's research to propel his recent success in treating PFB.

Dr. Ross runs a laser treatment center for PFB and other medical conditions. He recognized the potential for small and portable lasers to solve the PFB problem in the military. Hair removal lasers are now the best treatment for PFB. A 10-minute treatment given once a month inhibits hair growth and PFB.

PFB in the military would ideally be treated with a small, rugged, handheld portable device. Palomar Medical Technologies, the company that licensed Harvard's patents on laser hair removal, developed a prototype. A painless, portable way to prevent PFB could soon be available to the military.

Background

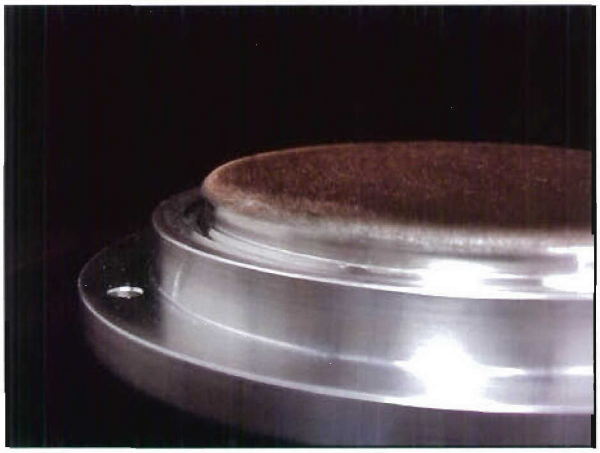
PFB is a disorder that occurs in people with wiry beards and is most common in men of African descent. Repeated, close shaving worsens the condition, because some shaved hairs have very sharp ends that puncture the skin as the hair grows. This can cause inflammation, bleeding, infection, and scarring.

PFB is especially troublesome for military personnel. Not shaving at all will cure PFB, but that is not an option since military personnel are required to adhere to strict shaving requirements. In addition, PFB prevents military people from getting a seal while wearing their gas masks.

Cesium Iodide Carbon Fiber Cathode Provides for a Variety of Applications

Payoff

The AFRL Directed Energy Directorate's cesium iodide carbon fiber cathode serves as a versatile, low work function, field emission cathode for a variety of applications, ranging from conventional and high-power microwave (HPM) tubes to X-ray tubes and flat-panel displays. The cathodes constitute a breakthrough in electron emitter technology, allowing efficient current emission with low out-gassing and long cathode lifetime.



Accomplishment

AFRL integrated the cathode into an existing HPM device, yielding impressive results and exceeding all previous capabilities of the HPM device under test. The cathode emits and shows no sign of impedance collapse, significant for long radio frequency (RF) pulse length operation. The cathode also does not appear to increase the out-gassing of the system, important to repetition rate capability and for the weight reduction of the overall system. The cathode emits at much lower voltages than any cathode previously used in the HPM device, allowing the HPM device to be used with a wider range of voltage and power operation. The HPM device can now operate at a lower power threshold, without having to throw away unused power. This leads to a plethora of convenient operation options with the new cathode.

At every voltage/current/pulse length setting tested, the resulting RF pulse tracked the voltage pulse in terms of rise time, pulse length, and fall time, a first for any cathode in the HPM device. This resulted in a significant increase in the overall energy efficiency of the device. The cesium iodide carbon fiber cathode operated at repetition rates up to 60 Hz with a total of greater than 10,000 shots and with no sign of performance or physical degradation. This greatly increases concept of operations options available to the warfighter.

Background

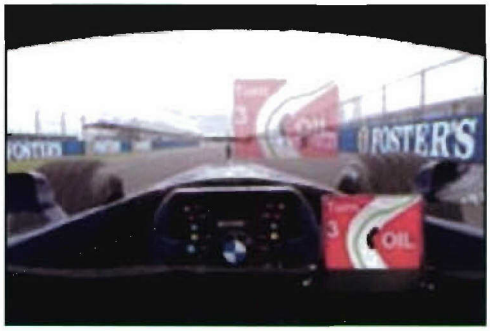
HPM devices require robust, long-lifetime, lightweight, high-current cathodes with low levels of neutral gas production. Traditional cathodes suffered either from short lifetimes and large amounts of neutral gas production, in the case of field emitters, or from low efficiency and large weights, in the case of thermionic emitters. Hence, AFRL required a significant improvement in cathode technology to make HPM devices feasible.

In 2001, AFRL completed testing of a prototype cathode in an idealized test geometry, demonstrating a lifetime of more than 1 million pulses. To prove operational feasibility in a real device, AFRL initially deployed the cathode in a single-shot HPM tube, with great success. However, repetition rate operation for long lifetimes remained unknown.

Technology Leads to First Snell-Approved Display System for Commercial Safety Helmets

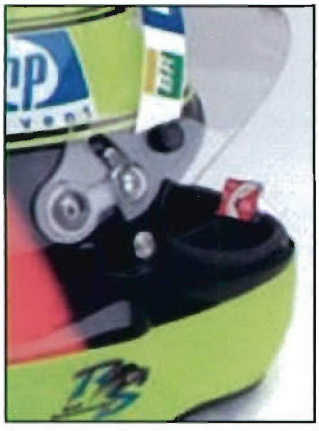
Payoff

Snell is known for its work in setting, maintaining, and upgrading the most authoritative helmet standards in the US and throughout the world. Anthropometry data and models developed by the AFRL Human Effectiveness Directorate have enhanced the capability of a protective helmet in the racing arena.



Accomplishment

AFRL's anthropometry expertise, data, and models resulted in the first Snell safety-approved integration of a display system for a BMW Formula 1 racing helmet prototype. BMW Group Technology in Palo Alto, California, and BMW Group DesignworksUSA, located in Newbury Park, California, developed the system.



Background

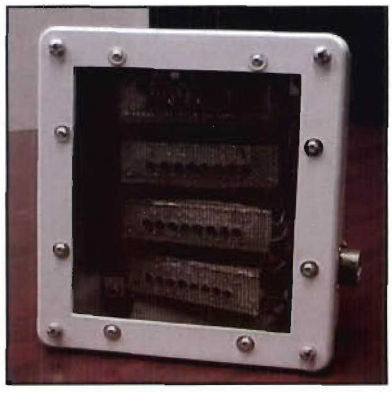
Protective helmets are one of the most effective means of preventing injury, permanent disability, or death in recreational and professional activities that incorporate speed and agility, like auto racing, motorcycling, and skiing. BMW consulted AFRL to find a solution for placing the display within the system as well as to assist in helmet sizing.

AFRL Anthropometry expertise became an integral part of the project. BMW Group DesignworksUSA reported that three-dimensional anthropometry data from AFRL helped bring about Snell's safety approval.

Active Acoustic Detector Maximizes Perimeter Protection and Solicits SBIR Phase III Proposal

Payoff

Current remote sensor systems are used to detect threats in homeland defense technologies, environmental protection, forensic sciences, and commercial industry. These remote sensor systems suffer from high false alarm rates and limited detection ranges. Adopting a multisensor approach that augments current sensors with an active acoustic detector will maximize security by reducing false alarms and detecting covert intruders.



Accomplishment

The AFRL Human Effectiveness Directorate sponsored the Digital Systems Resources (DSR), Inc., Phase II Small Business Innovation Research (SBIR) program to develop active acoustic sonar to add to the existing sensor suite. DSR developed the active acoustic detector, which activates an alarm after picking up targets ranging from high-velocity to slow and stealthy targets.

The current system provides covert, reliable detection of human intruders at tactically significant ranges, a drastic increase in range compared to seismic sensors. A field demonstration of the technology resulted in 100% intruder detection with limited false alarms. That success spurred the Electronics Systems Center to solicit a Phase III SBIR proposal from DSR.

Background

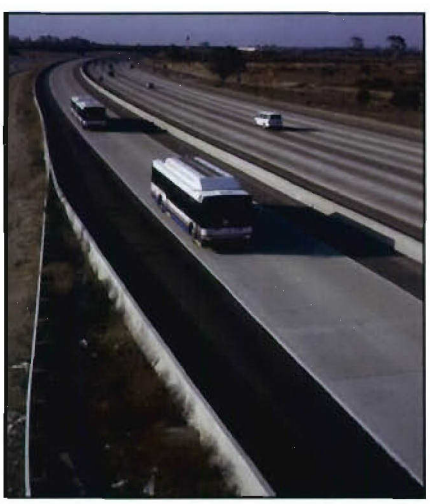
Modern remote sensor security systems use several sensing technologies including video and infrared. DSR used its expertise from years of experience with underwater sonar technology to apply sonar signal processing techniques to this innovation.

MoBIES Technology Participates in Automated Bus Control Demonstration

Payoff

MoBIES—"Take the Bus and Leave the Driving to Us." The California Department of Transportation (Caltrans) did just that recently when they took MoBIES (model-based integration of embedded software) on a test-drive to display automated vehicle control technologies. They accomplished this by executing cooperative multivehicle, highway-speed maneuvers with several specialized mass transit buses on a 7-mile stretch of Interstate (I) 15 in San Diego, California.

The AFRL Information Directorate is participating in MoBIES, a Defense Advanced Research Projects Agency Information Exploitation Office-sponsored program that is developing application-independent tool technologies for reusable component-based software for complex, real-time embedded systems. MoBIES technologies will benefit the Air Force due to their ability to counter increasing design time, cost, and risks associated with the growing complexity of embedded software for modern weapon systems.



Accomplishment

During the demonstration, Caltrans transit buses employed an experimental cooperative adaptive cruise control (CACC) system to automatically maintain a platoon formation at highway speed on I-15's reversible commuter lanes. During the testing and demonstrations, the lanes were closed to regular traffic.

The demonstration hardware included two 40 ft long compressed natural gas-fueled buses and one 60 ft long diesel-fueled bus. The buses were equipped with actuators (brakes and steering) and sensors (accelerometers, gyroscope, magnetometers, radar, and lidar). In addition, a wireless system was installed to allow vehicle-to-vehicle communication.

Onboard embedded software that controlled the vehicles' CACC system utilized MoBIES technology during the demonstration. The CACC system differs from traditional cruise control systems because the lead vehicle communicates its state information to a following vehicle. The following vehicle uses this information along with its own sensors to maintain a specified distance between itself and the lead vehicle. The development time for the entire supervisory portion of the longitudinal controller using MoBIES technology was significantly shorter than previous demonstrations without the technology.

Background

The MoBIES program has 14 contractors developing embedded software design tools and 3 open experimental platform contractors. AFRL, along with the University of California, Berkeley, and Caltrans, participated in this demonstration.

During the software development, several different levels of vehicle models were considered. Three simplified versions of the model were produced for formal verification purposes and to challenge problems for the MoBIES embedded software design tools. The three versions included a model with linear plant and controller, a model with nonlinear plant and controller, and one with nonlinear plant and controller that requires the use of a lookup table.

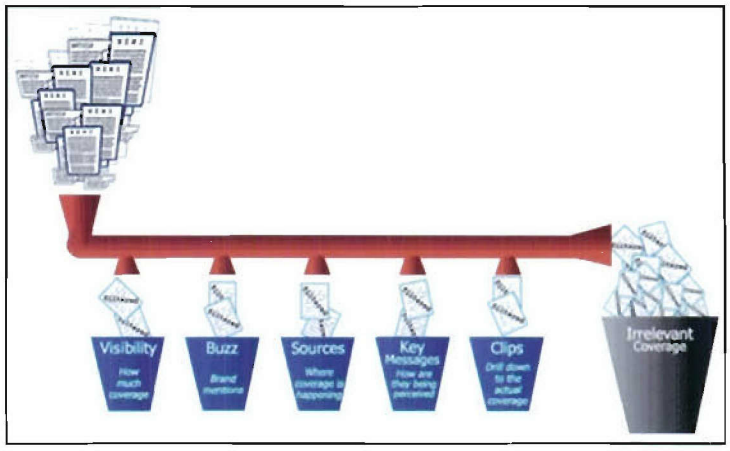
Software Development Produces a "Cymfony" of Information Extraction Tools

Payoff

A technology team from AFRL and Cymfony, Inc., Williamsville, New York, is significantly advancing state-of-the-art information extraction (IE) software technology. This technology identifies and extracts information from unstructured textual documents.

Accomplishment

While traditional IE is almost exclusively restricted to indexing based on keywords, research pursued by this team supports a more sophisticated form of IE based on a detailed grammatical analysis of source text. Text documents are processed based on the presence of important entities (e.g., names of people, places, companies, products, brands), relationships between entities (e.g., person "X" is employed by company "Y"), and key events such as the venture capital industry and management changes in companies.



The software uses a unique hybrid approach, exploiting the best techniques of statistical and grammar-based approaches. The software is domain independent and domain portable (it can be applied to new applications). Cymfony developed the advanced IE engine, InfoXtract, over a period of 5 years. AFRL support, via a number of Air Force Small Business Innovation Research contracts, played a major role in this development. The InfoXtract engine powers the Cymfony commercial product, Cymfony Dashboard, which monitors thousands of media sources and tracks when, where, how, and with whom brands are being discussed. Cymfony Dashboard helps companies target advertising campaigns to get more out of their marketing and public relations budgets.

Background

InfoXtract is being integrated into AFRL's Intermediate Text Exploitation Advanced Technology demonstration system to provide improved IE capabilities for military users at the National Air and Space Intelligence Center and, potentially, the Joint Warfare Analysis Center. Potential application areas for InfoXtract include monitoring of technical literature to support scientific research and development projects and health care delivery, where the use of IE is investigated to audit and process insurance claims by extracting diagnoses, symptoms, test results, and therapies from patient records, pharmaceutical companies, and information technology companies.

Diverse business applications include investment analysis support, where IE can be critically important to quickly handle enormous numbers of market news reports from news feeds, as well as content summarization for people who receive vast amounts of electronic mail.

Air Force Technology Aimed at Weapon Detection

Payoff

AFRL managed the technology development for the National Institute of Justice (NIJ) to detect small metal objects concealed by individuals. This technology was field-tested in a public high school in New York City. This next level of technology provides a safer school environment.

Accomplishment

The Air Force's Concealed Weapons Detection program, managed by the AFRL Information Directorate and NIJ's National Law Enforcement and Corrections Technology Center Northeast to assist criminal justice practitioners in developing, implementing, and evaluating modern technology, assisted the New York Police Department (NYPD) School Safety Division to effectively and efficiently screen students. The technology used was developed by the Department of Energy at the Idaho National Engineering and Environmental Laboratory and was licensed to View Systems, Inc. The SecureScan 2000™ magnetometer, a concealed weapons detection portal, was used for a detection demonstration at Taft High School in New York with the cooperation of the NYPD.

Only ferrous objects triggered the alarms when students passed through the SecureScan 2000. The system's unique advantage is its ability to pinpoint the location of the alarmed object, helping security personnel quickly identify the suspect item. Students walk through a portal similar to a traditional metal detector; however, cables carry sensor data to a nearby computer that displays a photo image on a monitor and pinpoints suspect objects. A magnetometer is not a metal detector; rather, it identifies objects that disturb the earth's natural magnetic field. The school's false alarm rate went down to 10% with the SecureScan 2000. The equipment can handle 300 students in 90 minutes and do a very thorough job.

Background

Small razor blade devices, wielded as part of gang-related activities, surfaced as a major security problem in New York schools several years ago. The NYPD School Safety Division personnel could fine-tune existing metal detectors to identify the threats; however, such sensitivity triggered alarms from every miniscule metallic object worn by thousands of students scanned each morning. With traditional detectors set at high sensitivity, nuisance objects such as zippers, coins, and body jewelry were setting off alarms. Security officials had to make split-second decisions on whether to hand-search each student.

Environmentally Friendly Anti-Icing/ Deicing Fluid Has Potential for Military and Commercial Applications

Payoff

A revolutionary, environmentally friendly anti-icing/deicing fluid (ADF) developed for military aircraft is now available commercially. The new ADF, developed under an Air Force Small Business Innovation Research (SBIR) effort managed by AFRL, is fully compliant with environmental regulations and is made from renewable resources.

Developed by METSS Corporation, of Columbus, Ohio, and known commercially as METSS ADF-2, the new fluid performs as well as products currently in use. METSS ADF-2 is so effective in removing and preventing ice buildup on fixed-wing aircraft surfaces, it is now being tested on rotor-winged aircraft (i.e., helicopters). ADF-2 has tremendous potential for both military and commercial applications.

Accomplishment

AFRL engineers with the Materials and Manufacturing Directorate managed the SBIR program that led to the successful development of a commercially viable, environmentally friendly replacement for glycol-based fluids, reducing or eliminating the need to capture or treat an ADF prior to releasing it into the environment. ADF-2 meets or exceeds performance objectives established under the SBIR program and was the first nonglycol, non-petroleum-based ADF certified by independent laboratories and recognized by the Federal Aviation Administration.

METSS ADF-2 technology is also certified for use as an aircraft lavatory antifreeze, potentially replacing thousands of gallons of propylene glycol-based fluids used in military and commercial aircraft. The new ADF earned an international Research and Development (R&D) 100 Award for 2001 from *R&D Magazine*, which convenes a panel of experts from industry and academia to review and rank nominations for selecting and recognizing the year's 100 most innovative and promising new technologies. This marks the third time in recent years the AFRL Materials and Manufacturing Directorate contributed to R&D that resulted in R&D 100 Award honors.

Background

Military and civilian airports use large quantities of glycol-based ADF. Unfortunately, one ADF (ethylene glycol) is toxic, and the other (propylene glycol) biodegrades too rapidly. Additionally, both require special handling to avoid environmental problems.

METSS ADF-2 effectively addresses all major toxicity issues, including fluid disposal, water contamination, and the high biological oxygen demand (BOD) associated with propylene glycol and the toxicity of ethylene glycol. BOD is important because commercial airports and military bases are increasingly concerned about the quality of storm water runoff and the effect of deicing chemicals on receiving waters. Discharge permits are required to monitor runoff to determine the BOD and presence of contaminants. AFRL's research and development effort reduced short-term BOD on receiving streams by about half when compared to propylene glycol, allowing twice as many aircraft to be deiced.

Unlike ethylene glycol, ADF-2 is nontoxic and nonhazardous to plant and animal life. It is 100% organic, biodegrades readily and completely with carbon dioxide and water, and contains no phosphates or urea, which can be harmful to natural waterways and fish. ADF-2 "waste" can be reused as a runway deicer. In addition, ADF-2 can be sprayed while aircraft engines are running. By comparison, many propylene glycol deicers cannot pass this test, since they use phosphate-based corrosion inhibitors.

Thin-Wall Cast Titanium Components Simplify Manufacturing Processes and Provide Cost Savings

Payoff

AFRL, working with industry, developed a thin-wall cast titanium nose cap for C-17 engine pylons that simplifies the manufacturing process, reduces component weight, and could save the Air Force (AF) an estimated $3.2 million. The results of the studies suggest several opportunities may exist to replace sheet metal fabrications and machined components with thin-wall titanium structural castings at a substantial cost savings and with modest weight reduction.

The studies showed that cost savings opportunities are maximized for more complex structures and assemblies, and they effectively demonstrated that thin-wall titanium castings technology is available for production implementation as opportunities arise. This could result in a savings of several million dollars for the AF. Advancements in thin-wall cast titanium will also benefit the commercial aerospace sector.

Accomplishment

AFRL's Materials and Manufacturing Directorate Metals Affordability Initiative (MAI) developed the new cap used to provide aerodynamic flow for the pylon. The initiative began in 1999 to reduce the cost of fabricating metal components for aerospace applications. AFRL researchers confirmed that Boeing, St. Louis, Missouri, plans to procure 60 of the new caps as a result of thin-wall titanium castings research and development studies. A redesign effort using the new technology is also under way on the C-17 transport's geometrically complicated fire seal used to protect the aircraft's structural assembly from potential fires in the engine pylons.

Background

AFRL created MAI to encourage technology development using lower-cost materials and manufacturing processes, efficient component designs, and tools and methods needed to reduce development and manufacturing times. Fifteen companies, representing a cross section of the aerospace metallic component supply chain, formed a consortium to address these key issues. Howmet Casting, of Whitehall, Michigan, and Boeing-St. Louis, two companies that have participated in MAI since its inception, have been striving to develop casting technology capable of producing thin-wall titanium engine and airframe structural components.

Their primary objective has been to reduce the cost of complex geometry components fabricated from sheet metal or machined from bulk material and also to systematically address and defeat barriers to the application of thin-walled (0.89-1.27 mm) cast components. This range represents a 30%-50% reduction in the thickness of current state-of-the-art thin walls, which have a lower thickness range of 1.5-2 mm.

Based on potential cost reductions and geometric complexity factors, Howmet Casting and Boeing-St. Louis teamed with AFRL to identify and select suitable structural components for planned thin-wall casting evaluations on the C-17 military transport aircraft. The selected components were engineered concurrently, using design features devised to overcome the technical challenges. Researchers used solidification modeling in several instances to identify the optimal gating arrangement. The team also evaluated key process variables using experiments designed to optimize the potential for success, conducted cost benefit analyses, and assessed how pervasive the new technology would be to both military and commercial products.

Scientists Discover Safe, Effective Solvent for Cleaning Aircraft Oxygen Lines

Payoff

Researchers from the AFRL Materials and Manufacturing Directorate's Fluids and Lubricants Group tested a variety of available solvents and identified a suitable replacement for Freon® 113. The new solvent is more environmentally safe and less hazardous to the ozone, and is currently being incorporated into the Air Force (AF) technical order for oxygen line cleaning.

Accomplishment

AFRL scientists and engineers recently teamed with the Aeronautical Systems Center (ASC) to identify a suitable, temporary replacement for Freon 113, a solvent used for wipe and liquid cleaning of liquid and gaseous oxygen systems in AF aircraft and ground service equipment. Analysis conducted and recommendations made by AFRL personnel revealed that AK 225G offers equivalent cleaning, is compliant with environmental regulations, and is as safe as Freon 113, which was widely used before production of the halogenated solvent was banned due to its ozone depleting tendencies.

Background

Freon 113 TF solvent, 1, 1, 2-trichlorotrifluoroethane (Freon 113) was widely used by aircraft maintainers to clean equipment, including oxygen lines, which deliver liquid and gaseous oxygen within an aircraft. However, tougher environmental regulations have led to the ban of many halogenated solvents because of their ozone depleting tendencies. When production of Freon 113 was discontinued, users desperately sought a robust, environmentally friendly substitute that would perform at least as well as Freon 113.

In many cases, maintainers found that candidate substitutes did not work as well as the previous solvent or had other characteristics that made them less than ideal. In addition, it was often difficult to assess various solvents based on the manufacturers' claims. So, scientists and engineers from AFRL and ASC designed a program to identify replacement solvents for wipe and liquid cleaning of liquid and gaseous oxygen systems. ASC provided funding and leadership for the project.

Seven solvents that were advocated as Freon 113 replacements were evaluated during testing at AFRL; the National Aeronautics and Space Administration's White Sands Testing Facility; the Phoenix Chemical Laboratory in Chicago, Illinois; and Edwards Air Force Base, California. Using Freon 113 as the baseline, engineers conducted several tests to determine the solvents' ability to clean oxygen system components.

Directorate experts evaluated the results of extensive testing and determined that AK 225G, a hydrochlorofluorocarbon produced by Asahi Glass Corporation, would provide an appropriate midterm replacement for Freon 113. The solvent has far less severe ozone depleting tendencies and offers simple wipe cleaning properties equivalent to Freon 113. AK 225G is currently being incorporated into the AF technical order for oxygen line cleaning.

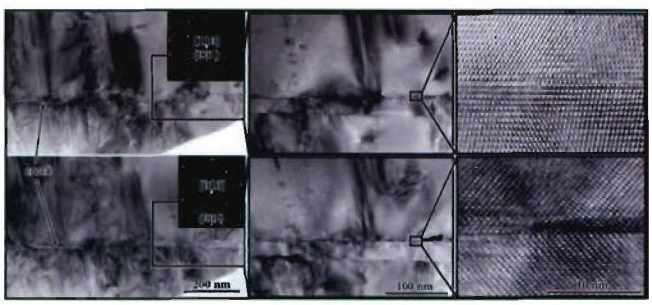
Materials Research in Monazite Deformation Twinning Benefits Science and Defense

Payoff

AFRL scientists made significant advancements in understanding a phenomenon called deformation twinning, a major materials deformation mode occurring particularly at low temperatures and high strain rates. Working with industry, the researchers succeeded in identifying five deformation twin modes in monazite, a complex mineral with low symmetry. The knowledge and insight gained through these efforts will advance technologies critical to tomorrow's defense needs, enhance the performance of important commercial products, and promote the creation of new technologies and products within the private sector.

Accomplishment

The AFRL Materials and Manufacturing Directorate, working with Rockwell Scientific Company, Thousand Oaks, California, deformed polycrystalline monazite at room temperature using a spherical indenter. Scientists have been able to explain the existence of these modes with fundamental principles that should be useful for prediction in systems that are more complex. These studies help provide the knowledge required to create more advanced tools for analyzing the composition and application potential of minerals and other natural materials valuable to systems developed for national defense. They also aid in the research and development of dynamic new commercial products.



Background

Twinning, a natural phenomenon in crystal alignment, originates in one of three ways: via growth twinning, transformation twinning, or deformation twinning. Growth twinning occurs as a result of accidents during crystal growth, resulting in a new crystal being added to the face of an existing one. Transformation twinning occurs as a strain accommodation mechanism during phase transformations induced by pressure or temperature. Deformation twinning occurs when lattice points in one crystal are sheared to resemble lattice points in another crystal, creating symmetry. Deformation twinning is a common plasticity mechanism in body-centered cubic metals. The process is less understood in more complex materials but is typically the dominant deformation mechanism at low temperatures and high strain rates, which makes it of particular interest for impact-resistant materials.

Naturally occurring monazite is typically a reddish brown mineral whose name derives from the Greek word "monazit," meaning "to be alone," because it was considered extremely rare when first discovered. It contains the rare earth elements cerium, lanthanum, and neodymium, as well as the radioactive element thorium. Monazite's rare earth elements are used in high-performance magnets; as pigment in ceramics; and in robot motors, fiber optics, X-ray screens, energy-efficient lanthanum lamps, and color television tubes.

Monazite has received attention for its use in structural ceramics that rely on the mineral's unusual combination of properties, including high temperature stability, compatibility with common structural oxide ceramics, relatively low hardness, and weak bonding with other oxide ceramics. The low hardness and weak bonding are especially important for machined ceramics, where they enable material removal, and for fiber-reinforced composites, where they allow crack deflection and fiber pullout, without the problem of oxidation experienced by more commonly used interfaces.

High-Performance Modulators Spark Second Phase of Photonics Revolution

Payoff

AFRL scientists and engineers, working in conjunction with Air Force (AF) contractor IPITEK, achieved significant advancements in the research and development of low-cost, high-performance electro-optic polymer modulators instrumental in achieving very high modulation rate signals on optical carrier beams. Electro-optic polymer modulators satisfy a number of current and future military needs. The commercial potential for low-cost, high-performance electro-optic polymer modulator technology could impact the entire spectrum of information communication systems. The commercial market potential for fiber-to-the-home technology is huge, given the estimated 100 million households and 50 million potential commercial and institutional users in the US alone.

Accomplishment

The AFRL Materials and Manufacturing Directorate transitioned this new technology base to the AF and Department of Defense. Technology transfer for commercial applications is also ongoing and could mark the beginning of a second phase of the photonics revolution that began more than 2 decades ago.

Electro-optic polymers are an intense AF-sponsored research and development effort, and remarkable improvements in their performance have been seen the past 15 years. Building on the gains made in previous research, IPITEK designed a program to tackle the challenging science and engineering problems of transitioning these materials into current, state-of-the-art commercial and military systems.

Background

After more than 2 decades of the first phase of the photonics/fiber-optics revolution, there is now an increasing need for transmitting vast amounts of information and in particular, a need for active optical switching within networks. There are also important military uses, such as, intersatellite communications and phased-array radar. Inherent in all of these systems is the necessity to impress very high modulation rate signals on optical carrier beams, whether done in an analog or digital fashion.

The commercial potential for the technology developed under this dual-use program is huge. The primary market being targeted is the cable television distribution market, which could become a major Internet distribution market as well. Electro-optic polymer technology can also be adapted to ultra-high-frequency electromagnetic field sensors for numerous military applications. The unique advantages of such field sensors include the ability to make compact sensor arrays and minimal disturbance of the electromagnetic fields being sensed due to the all-dielectric materials being employed. Another important application of this technology involves high-speed, digitally tunable wavelength filters, which are key devices for dynamically reconfigurable optical add-drop multiplexers in fiber-optical networks.

Advanced Fuel Cell Research and Development Effort

Payoff

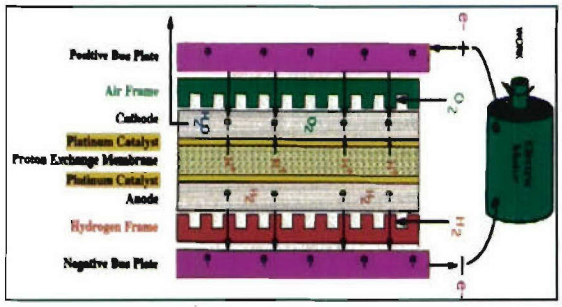
The Air Force (AF) and the other military services depend on varied forms of power generation and storage, including fuel cells. AFRL scientists are developing a new class of polymeric materials for electrolyte membranes in fuel cells that are more than five times as efficient as the state-of-the-art material perfluorinated aliphatic ionomer Nafion-H. This program will help provide lightweight, smaller-footprint power generation sources required to ease deployment logistics. These fuel cells will also benefit fuel cell vehicles such as cars, trucks, and buses, as well as portable fuel cell generators for powering laptop computers, cell phones, and video devices.

Accomplishment

The AFRL Materials and Manufacturing Directorate's in-house research will dramatically improve the performance of proton exchange membranes (PEM) through the introduction of new polymer materials, such as highly sulfonated polyarylenethioether-slfone, by an enormous increase in proton conductivity. This, in turn, will allow the AF to develop fuel cells that are smaller and significantly lighter for a wide range of vital applications, ranging from integrated power units on board aircraft to unmanned air vehicles. Increasing fuel cell power density, while reducing weight, also offers tremendous potential for the commercial sector.

Background

AFRL's new approach uses a wholly aromatic polymer backbone, along with a high sulfonic acid content that enhances water retention for potential high-temperature (>120°C) fuel cell applications. In a key study, the AFRL team incorporated bulky aromatic groups to end-cap the sulfonated polyarylenethioethersulfone polymer structures. The objectives for using end-caps on the polymers were to increase water resistance while retaining high proton conductivity and hydration sensitivity, as well as to narrow the molecular weight distribution, increase the use temperature, and decrease polymer susceptibility to oxidation due to thiol end-groups.



The PEMs developed by AFRL Materials and Manufacturing Directorate scientists, in collaboration with the AFRL Propulsion Directorate, were successfully integrated into membrane electrode assemblies (MEA) for evaluation and testing critical to the ultimate performance of a fuel cell device. The PEMs performed very well in the MEAs, providing power densities twice as high as those of Nafion-H tested under the same conditions of temperature and relative humidity.

PEM fuel cells use a simple chemical process to combine hydrogen and oxygen into water, producing an electric current during operation. A fuel cell is quiet, efficient, and clean. Fuel cells running on hydrogen produce no pollution, the only by-product being pure water.

Additionally, they have a 50% efficiency rate as opposed to conventional internal combustion engines, which are only 12%–15% efficient. Since no moving parts are involved, PEM fuel cells can be extremely reliable and create almost no noise. Most importantly, they have many critical applications within the AF and throughout the Department of Defense as well as the commercial sector. Continued research in this area of investigation could lead to important solutions to some of today's most complicated power generation challenges.

Commercialization of Composite Structure Design Technology

Payoff

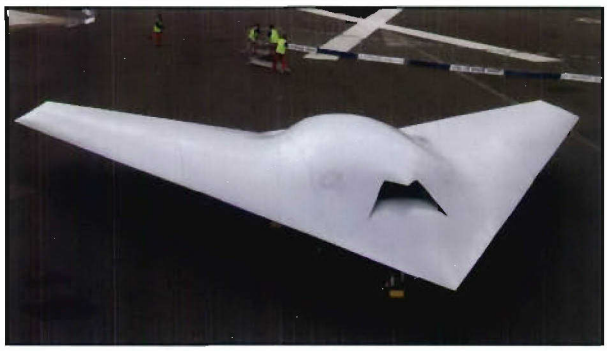
Officials from the AFRL Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division and the AFRL Air Vehicles (VA) Directorate announced that key structural analysis software developed under the Composites Affordability Initiative (CAI) team banner will be commercialized by ABAQUS, Inc. This will ensure long-term government/industry investment in advanced structural analysis tools.

Accomplishment

ManTech leads the CAI team, which includes representatives from VA, Boeing, Lockheed Martin, Northrop Grumman, and Bell Helicopter. This software extends new and unprecedented capabilities to state-of-the-art structural analysis tools by allowing the user to predict not only when the structure will fail, but also how that damage will grow and progress, thereby allowing all concerned a more complete picture of the durability and damage tolerance of advanced composite structures. The technology is currently used extensively within the Boeing 7E7 and Air Force X-45C programs.

Background

Typical finite element analysis predicts where and under what conditions a structure will fail. In order to increase the confidence to use advanced composite structural designs (being matured under CAI), the CAI team pursued improvements. Users are also concerned about how the damage will progress in order to understand the full impact of damage and the durability of the structural design.



Boeing developed the Virtual Crack Closure Technique (VCCT) under contract with the CAI team. VCCT plays an important role by providing unprecedented capability for the design of aerospace structures involving composites. Under AFRL leadership, Boeing developed, refined, and proved the VCCT approach for predicting the reliability of major composite structural components during the past several years. Boeing and ABAQUS, Inc., have applied for a patent, and ABAQUS will market the VCCT technology commercially.

Breakthrough BBW Technology Applications in Automotive Industry Could Lead to Improved Braking Systems for UAVs

Payoff

Successful design, development, and application of brake-by-wire (BBW) technology benefits consumers, the automotive industry, and the Air Force (AF). BBW technology offers a demonstrated potential to improve how brake systems are manufactured and implemented, and enhances safety and vehicle stability at costs comparable to or less than conventional hydraulic braking systems. Planned follow-on research efforts between Delphi Automotive Systems, of Dayton, Ohio, and AFRL could lead to lighter-weight braking systems for unmanned air vehicles (UAV), extending their reach and reducing fuel consumption costs.

Accomplishment

The AFRL Materials and Manufacturing Directorate and the National Center for Industrial Competitiveness concluded an innovative, 2-year cooperative research and development agreement. By using technology developed for military aircraft, researchers were able to design, construct, and successfully demonstrate a commercially viable BBW system for next-generation automobiles. To achieve this, Delphi Automotive Systems, the principle agent for the experiment, relied heavily on fly-by-wire technology and landing gear expertise developed and honed by the AF.

The technical knowledge and insight gained from this experiment allows Delphi to compete globally in the development of both hybrid and full-electric BBW design options. It also allows the AF, via a follow-on agreement between Delphi and AFRL, to pursue reduced-cost design and development of high-performance electromechanical braking system for UAVs.

Background

Eliminating hydraulics is an AF goal. The change to electromechanical braking systems will be more environmentally friendly and offer great opportunities for enhanced vehicle safety, mission survivability, and manufacturing efficiency. The fundamental need is to advance the technology to a stage where electromechanical activation is competitive with very mature hydraulic systems. The knowledge obtained from this BBW research and development effort increases that potential.

The BBW project demonstrates that government and private industry can work together to advance mutually beneficial technology objectives. The BBW project has the potential to reduce component costs through shared demand and to leverage investments in "more electric" aircraft, while providing needed large-scale technology validation.

Student Research Cooperative Agreement Provides Unique Learning Experience

Payoff

The AFRL Materials and Manufacturing Directorate and the Southwestern Ohio Council for Higher Education (SOCHE) are providing 45 college and university students with a unique educational and career enrichment opportunity under the Student Research Program. Students benefit academically and financially by working in a state-of-the-art laboratory. AFRL gains the help of a dynamic workforce and increases the potential for gaining highly skilled research specialists with strong educational backgrounds and outstanding on-the-job credentials.

Accomplishment

Under the program, undergraduate and graduate students with technical disciplines have a chance to enhance their ongoing courses of study and earn stipends while working in state-of-the-art research facilities supporting the Air Force and national security. This year's program includes students from 5 major colleges and universities, representing 10 fields of study. The students perform hands-on work with AFRL scientists, engineers, and technicians; conduct important research; and provide other valuable support throughout the complex. Various learning opportunities such as internships, senior projects, cooperative education, and graduate research, along with flexible schedules and hours, can be arranged with the Student Research Program Office.

Background

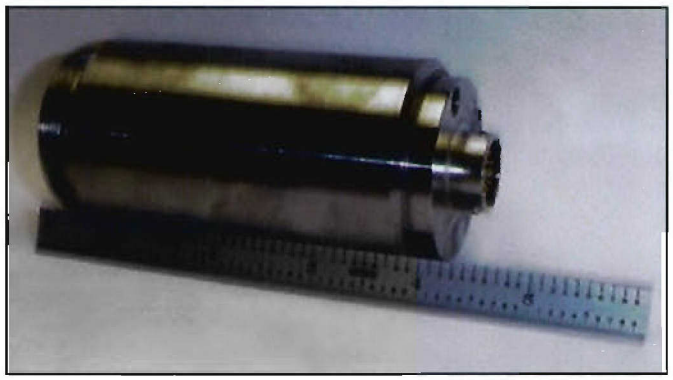
SOCHE is a consortium comprised of 20 major colleges and universities, 1 foundation, and 2 corporations. The consortium was founded in 1967 by 10 of these members to promote service and interinstitutional cooperation; organize conferences for representatives of teaching and research faculties and staffs, and library and administrative staffs; serve as a clearinghouse for the exchange of information; conduct cooperative programs in teaching, research, and enrichment of student life; and foster lecturers, concerts, and exhibits.

Since its foundation, SOCHE has worked with area colleges, universities, and professional organizations to promote educational advancement in the Southwestern Ohio region. AFRL teamed with SOCHE in 1988, and today the council's on-base program at Wright-Patterson Air Force Base (AFB), Dayton, provides member organizations with a necessary liaison to the base by serving as a clearinghouse for educational information and as an office for preliminary academic advising to Wright-Patterson employees and their families.

Multiple-Event Hard-Target Fuze Transitions to UK's Precision-Guided Bomb Program

Payoff

AFRL transitioned to the United Kingdom's (UK) Precision-Guided Bomb (PGB) program the first low-cost, all-electronic smart penetration fuze with improved ability over existing fuzes to survive rigid body deceleration shock and discriminate target layers. The fuze can survive high-impact conditions, increasing the ability of penetrating munitions to defeat underground bunkers. It provides an accurate and low-cost solution to fuzing for hard-target defeat. The PGB program will enhance the potential to transition this technology to future US weapon systems, including high-speed weapons.



Accomplishment

Alliant Techsystems (ATK) Ordnance and Ground Systems, in Plymouth, Minnesota, and Thales Missile Electronics (TME), in Basingstoke, UK, developed the multiple-event hard-target fuze (MEHTF) smart penetration fuze for AFRL's Munitions Directorate. The MEHTF smart penetration fuze uses an accelerometer to measure distance traveled and to count voids and layers.

The PGB fuze development strives to meet current and future UK requirements for intelligent penetration fuzing. Using a partnering arrangement, ATK and TME are developing and manufacturing the PGB fuze, utilizing MEHTF technology. The ATK/TME team modified the MEHTF design to meet the PGB program's needs. This technology transition was facilitated by a US/UK government-to-government project arrangement to share information and hardware and perform testing in the smart fuzing technology area.

Background

The MEHTF program was initiated to address anticipated fuzing needs for future penetrating weapons and was structured to identify and address specific technology limitations associated with several future applications requiring a smart penetration fuze. These limitations include (1) survivability under severe shock loads associated with high-speed penetrator impact, (2) reduced-size fuze wells of future small penetrators, (3) high cost of previous smart fuzes not competitive with time-delay fuzing, (4) limited accuracy in target media discrimination, and (5) future need for a multiple-event capability for complex multifunction warheads.

Testing of YBCO Superconducting Coils Completed

Payoff

AFRL's successful testing of new high-temperature superconducting (HTS) simple coils, made with yttrium barium copper oxide (YBCO)-coated conductor materials, provides an enabling technology that is essential in the development of future compact, high-power airborne generator systems. This successful technology is needed to design and develop future advanced compact, high-power generator coils for aerospace applications.

Accomplishment

The AFRL Propulsion Directorate completed testing of the first superconducting magnetic coils to use industrially made YBCO-coated conductor material. AFRL conducted the tests with Long Electromagnetics, Inc.; American Superconductor Corporation; and SuperPower, Inc., using various programs including the Dual-Use Science and Technology program. During testing, different coils were made using laboratory-developed winding techniques. The YBCO-coated superconductor endured significantly greater stresses during the tests and outperformed the earlier generations of HTS conductors.

Background

Compact, high-power generators are needed for airborne directed energy weapons. A Defense Production Act–Title III program was initiated to establish manufacturing facilities for the YBCO-coated conductor.

The testing indicated that no reduction in the n-value occurred at the 77°K operating temperature. The n-value describes the relationship of the voltage drop across the wire to the applied current. For the transition from zero resistance (zero voltage drop) to a finite resistance (finite voltage drop), the I-V curve of HTS wires can almost always be fit with the power law $E(j) = Ec\ (j/jc)n$. $E(j)$ is the longitudinal voltage drop across the superconductor, Ec is the electric field criterion, j is the applied current density, jc is the critical current density, and n is the exponent. For a sharper transition, the I-V curve has a higher n-value. The n-value is often used to determine the quality of the bulk superconducting material.

Education Partnership Enriches Chemistry and Physics Instruction at Antelope Valley College

Payoff

The Antelope Valley Career Prep Council's School-to-Careers consortium presented the AFRL Propulsion Directorate with an annual award in recognition of its more than 13 years of educational outreach efforts in the southern California area. AFRL continues to expand its outreach efforts, assisting educational facilities, instructors, and students with modern equipment and educational opportunities. For more than 55 years, the men and women of AFRL's Edwards Research Site have provided the nation with the rocket propulsion technology research, development, and testing needed to access space and defend the country.

Accomplishment

AFRL signed Educational Partnership Agreements (EPA) with several high school districts and college/university partnerships in the southern California area, enabling its partners to obtain laboratory equipment to enhance their chemistry and physics educational capabilities. AFRL entered into an EPA with the Antelope Valley College, located in Lancaster, California, and loaned automated scientific laboratory equipment to its physics and chemistry classes. The EPA also provides opportunities for teaching assistance, involves students in AFRL research projects, and furthers equipment support including items needed for materials engineering laboratories.

Similar efforts are under way with recent EPAs with the Mojave and Antelope Valley Union High School districts. The EPAs will provide classroom equipment and pathways for students to enrich their education in the sciences. Currently, almost every high school chemistry and physics class in the Antelope Valley will be enriched by nearly $120,000 worth of equipment and materials from AFRL.

One of the most significant changes in the region is the recent announcement of a 4-year engineering degree program at the Lancaster University Center, a partnership of the Antelope Valley College, California State University-Bakersfield, California State University-Fresno, and the city of Lancaster. As a consortium member, the AFRL Propulsion Directorate will support a full-time mechanical engineering professor and the laboratory equipment for 3 years.

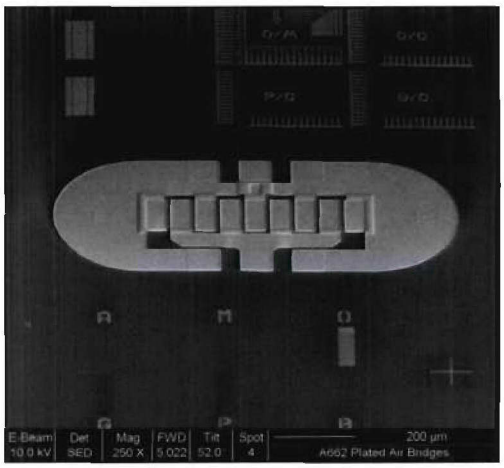
Background

The nation's defense establishment is facing a severe shortage of scientists and engineers during the next decade as a large percentage of the existing workforce reaches retirement age. AFRL is doing its part by developing programs that will attract more students to the scientific and engineering career fields. AFRL not only supports numerous career days, science fairs, and laboratory tours for schools, but also participates in the Antelope Valley's Math, Science, and Engineering Technology consortium; Career Prep Council's School-to-Careers program; and Kern Science Foundation.

Passivation Approach Reduces RF HEMT Gate and Drain Lag

Payoff

AFRL overcame a significant technical barrier to the high-performance operation of aluminum gallium nitride (AlGaN) /gallium nitride (GaN) high electron mobility transistors (HEMT) at X-band frequencies. AFRL scientists found that wide bandgap materials such as scandium oxide or magnesium oxide, when used as a passivation layer on radio frequency (RF) HEMTs, significantly reduces the gate and drain lag effect in the HEMT. This, in turn, improves the device's ability to operate under high-power and high-frequency conditions. The long-term benefits of the new passivation approach will improve RF transistor performance and reliability for advanced sensor systems that operate at microwave and millimeter-wave frequencies.



Accomplishment

AFRL's Sensors Directorate RF Devices Team designed a set of experiments to pinpoint the root cause for dispersion in these devices and then tested a number of potential solutions. AFRL collaborated with the University of Florida, who provided molecular beam epitaxial growth of wide bandgap HEMT materials. The team processed the semiconductor material in AFRL's Compound Semiconductor Clean Room Device Facility.

Department of Defense contractors in the wide bandgap semiconductor arena are interested in this laboratory-developed passivation process. One industrial partner is working with the RF Device Team and the University of Florida to transfer and integrate the developed passivation technology into its HEMT fabrication process.

Background

The thin HEMT structure was grown on a 2 in. diameter silicon carbide (SiC) substrate wafer using a metal organic chemical vapor deposition process. The RF Devices Team started with the rigorous process of fabricating HEMT devices on the AlGaN/GaN HEMT material structure. The 2 in. SiC substrate wafer supports the device layers during the processing steps, one of which involves complicated electron beam writing of photoresist to create fine metal geometries on the wafer.

These metal gates serve as the modulating electrode for the HEMT, which typically sources moderate current at low voltages. However, when the wide bandgap passivation is applied to the wafer, both the current and the voltage for the device rise dramatically. In addition, the modulation becomes more efficient at high frequencies (10 GHz), where the high-power operation of the device is needed for many military sensor applications, including phased-array radar, electronic warfare jammers, and RF communications transmitters.

AFRL Technique Helps Intel Create Breakthrough Device

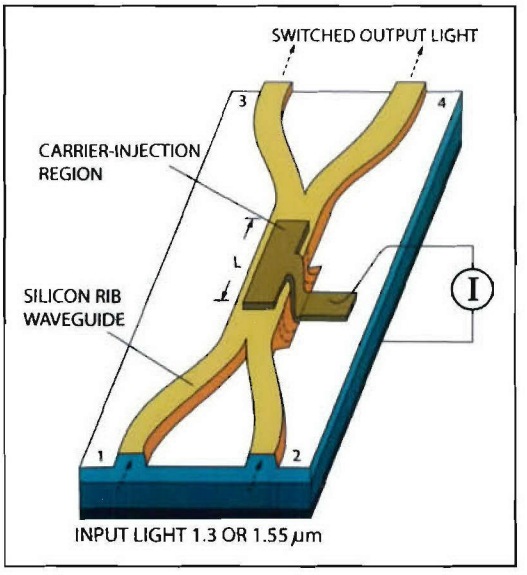
Payoff

Intel Corporation's breakthrough in optical modulator technology—the achievement of greater than 1 GHz modulation rates in silicon devices—exploited results of Air Force in-house laboratory research that was sponsored by AFRL Air Force Office of Scientific Research. To create its high-speed silicon-based device, Intel employed a carrier-induced modulation technique proposed in the 1980s by Dr. Richard Soref, of the AFRL Sensors Directorate's Optoelectronic Technology Branch, Hanscom Air Force Base, Massachusetts. (A schematic of a device reported by Dr. Soref and Mr. Joseph Lorenzo is shown in the illustration.) By "siliconizing" photonics, Intel plans to use its silicon technology and high-volume manufacturing capabilities to advance optical communications. These silicon photonic devices will likely be used to build high-speed busses, as well as connections among servers, personal computers, and other electronic components.

Accomplishment

Dr. Soref, an innovator in silicon-based photonics and optoelectronics, has invented many types of silicon-based waveguides and waveguide-integrated photodetectors. Intel plans future investments in silicon photonics, an area in which Dr. Soref and his collaborators are pioneers.

One of the major limitations of silicon photonics has been the relatively low speed of silicon-based optical devices compared to those fabricated from Periodic Table Group III-V semiconductors or lithium niobate. Until 2004, the fastest silicon-based optical modulator demonstrated experimentally had a modulation frequency of only 20 MHz. Now, utilizing the physical mechanism previously investigated by Dr. Soref and his collaborators in slower prototypes, Intel has brought silicon-based light modulation into the GHz frequency range—more than 50 times the previous research record. These advances, along with advanced assembly techniques, will enable silicon components to attain high bandwidth at significantly lower costs than were previously possible.



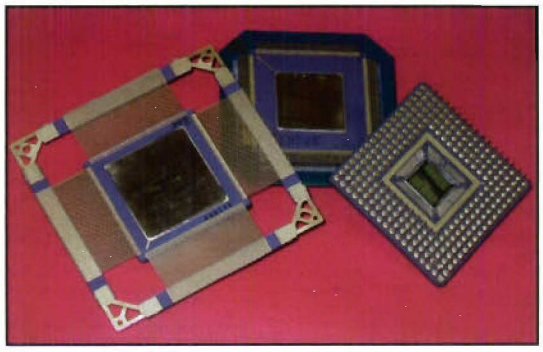
Background

Silicon photonics is the technology of making active and passive optical devices from silicon and standard complementary metal oxide semiconductor manufacturing techniques. Fast modulation has been one of the critical technical barriers to realizing practical, on-chip, integrated optical circuits for telecommunications applications.

Foreign Comparative Testing of Space-Qualified Digital Signal Processor Products

Payoff

AFRL successfully managed radiation testing of radiation-hardened digital signal processor (DSP) devices and boards, resulting in delivery of vital technical information to the Military Satellite Communications (MILSATCOM) Joint Program Office (JPO) and National Polar-orbiting Operational Environmental Satellite System (NPOESS) Integrated Program Office (IPO).

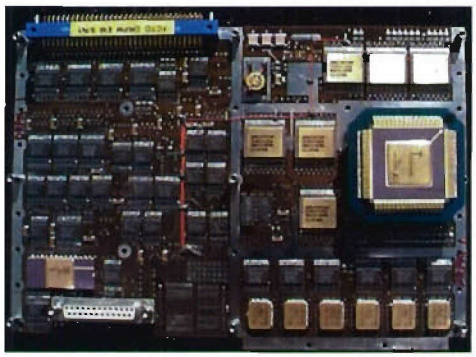


Accomplishment

AFRL's Space Vehicles Directorate, as program and technical manager of a Foreign Comparative Testing (FCT) program, tested both foreign and domestic DSP products in appropriate space radiation environments. A team of government and contractor personnel tested the BAE Systems RH21020 device, the Atmel TSC21020 device, the Analog Devices ADSP21020 device, the Northrop Grumman advanced extremely high frequency (AEHF) controller board (not pictured), and the Austrian Aerospace digital receiver processor module (DRPM) board. AFRL used six different radiation test facilities in five states for this testing.

AFRL engineers tested devices in total ionizing dose, prompt dose, single-event effects (SEE), and proton and neutron radiation environments. They tested the AEHF controller board in the prompt dose environment, while testing the DRPM board in the total ionizing dose (at high and low dose rates) and SEE environments.

Test results gave MILSATCOM and NPOESS valuable technical information. Atmel's DSP allows MILSATCOM a viable replacement if no onshore source reappears. Also, NPOESS can confidently procure this offshore DRPM as a representative part of its Global Positioning System Occultation Sensor's (GPSOS) expected radiation performance.



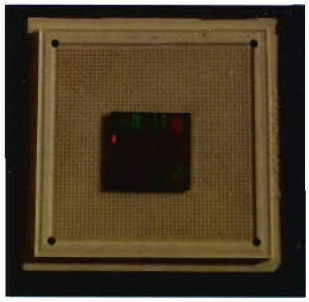
Background

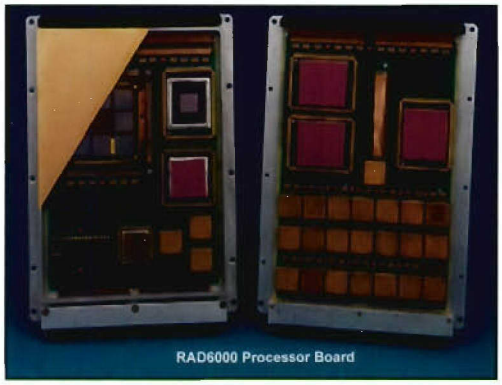
The FCT program, funded by the Office of the Secretary of Defense and directed by the Air Force (AF) FCT Office, determines the applicability of foreign technology to AF programs, finds second sources for current AF technology, and determines the efficacy of foreign technology to meet AF requirements. The MILSATCOM JPO sponsored the AF FCT program and baselined the 21020 DSP for its AEHF controller board. The NPOESS IPO also sponsored the AF FCT program and baselined the Austrian Aerospace DRPM board for its GPSOS.

RAD6000 Microprocessor Goes Back to Mars

Payoff

The AFRL Space Vehicles Directorate developed microprocessors that control the twin Mars robotic rovers, Spirit and Opportunity. AFRL's 32-bit microprocessor is called the RAD6000, manufactured for the Air Force by BAE Systems. The RAD6000 is now flying in approximately 100 military, scientific, and commercial satellites, and has logged years of flight time without a computer failure.





RAD6000 Processor Board

Accomplishment

AFRL's RAD6000 is now an old hand on Mars, as it was also the main computer for the Pathfinder lander in 1997. The RAD6000 computers for the current rovers not only control the robotic vehicles on the surface, but also served as the main mission computers for the Earth to Mars mission.

A RAD6000 microprocessor is also controlling the Stardust spacecraft, which encountered the comet Wild 2 and will bring back samples of the comet's dust. Stardust's designers had enough confidence in the RAD6000 to use it in a single string configuration with no backup for the 7-year mission.

The RAD6000 is not only the first radiation-hardened 32-bit microprocessor. At 1.1 million transistors, it is also the most complex radiation-hardened chip ever produced and the most complex commercial component to be transferred to a hardened process. The RAD6000 is based on IBM's commercial RS/6000 microprocessor, which is a direct predecessor to today's PowerPC™ series of microprocessors.

Background

The RAD6000 chip was the world's first radiation-hardened 32-bit microprocessor, developed in 1994 by AFRL's Advanced Spaceborne Computer Module program. For military or civil space use, BAE Systems (formerly Lockheed Martin Federal Systems) had to harden the IBM RS/6000 design against the space radiation environment. The memory elements (registers and caches) were redesigned to withstand bit upsets or flips caused by cosmic ray strikes, and the microprocessor was refabricated in BAE's radiation-hardened chip foundry for ionizing radiation hardness. Without these modifications, a commercial microprocessor would perform erratically and unreliably in space.

STARBASE: We Have Liftoff!

Payoff

The AFRL Space Vehicles and Directed Energy Directorates launched a novel education program, STARBASE® *La Luz* Academy. The academy is an effort to help mitigate an anticipated shortfall of future scientists and engineers critical to maintaining America's technological edge in national defense. AFRL is inspiring future scientists, engineers, and astronauts by providing hands-on experiences for students from the 5th grade through college.

Accomplishment

Working with local schools, AFRL developed extracurricular coursework in a classroom and hands-on research setting to present science and math in a practical, palatable way to students who otherwise might avoid these subjects. Students get to work with AFRL scientists and engineers and other federal and private organizations responsible for creating technology needed by the military. The STARBASE goals are to line up elementary and secondary students for potential future careers as scientists and engineers, not only with the Air Force (AF), but also with other federal research institutions, universities, and private companies that develop much of the nation's defense technology.

Background

Congresswoman Heather Wilson launched the first AF STARBASE in a ribbon-cutting ceremony at AFRL's Phillips Research Site, Kirtland Air Force Base, New Mexico. The AF STARBASE *La Luz* Academy has three main components, consisting of five flights. These flights are designed to provide continuity for students as they progress from elementary to middle school and from middle to high school.

The Mars Missions flight, for 5th-grade students, is based on the Challenger Center for Space Science Education's acclaimed Marsville, the Cosmic Village® program. It simulates students preparing for a manned mission to Mars and culminates in a Link-Up Day event where students come together to build a Martian colony.

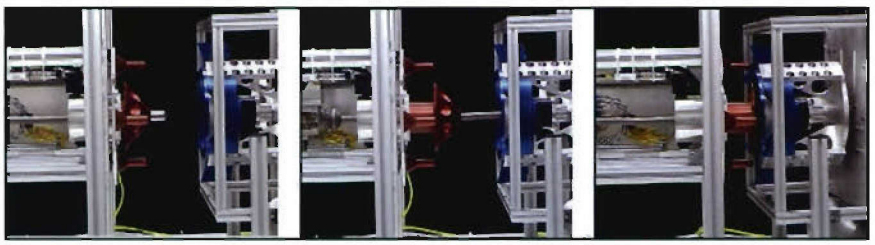
Providing Engineering and Technology Experiences for Students (PETES) flights, for middle school students, engage students in a series of fun, educational, hands-on curriculum days centered around AFRL technologies. PETES students also serve as mentors during the Mars Missions flight Link-Up Day event.

The Students Planning and Conducting Engineering (SPACE) flight, for high school students, engages students in a multiyear, real-world research and development (R&D) activity under the guidance of scientists and engineers volunteering as mentors. At the end of each school year, the SPACE students present their R&D accomplishments, problems, and plans for the next year to their peers, mentors, and various dignitaries at the annual SPACE Symposium. PETES students are invited to attend the symposium to listen to the formal presentations, visit the SPACE student display booths, and share their own experiences in the PETES flight with others.

Autonomous Satellite Docking Mechanism Developed for On-Orbit Servicing

Payoff

The AFRL Space Vehicles Directorate; Microcosm, Inc.; and Michigan Aerospace Corporation developed the autonomous satellite docking mechanism under a Small Business Innovation Research Phase II enhancement. The mechanism is an enabling technology for future on-orbit servicing systems. In addition, it is a potential alternative for future Orbital Express missions, which will provide additional options for military and commercial customers.



Accomplishment

Current satellite systems require years to design, build, and launch. After launch, it is nearly impossible to repair, upgrade, or reconfigure the satellite. AFRL; Microcosm, Inc.; and Michigan Aerospace Corporation took a step to solve this problem through the development of an autonomous satellite docking mechanism. The docking mechanism was put to the test on the National Aeronautics and Space Administration's KC-135 microgravity research aircraft. The mechanism successfully completed 62 different docking operations on four 2-hour flights.

The docking mechanism utilizes a flexible cable to initially contact and capture the target vehicle with a minimum of imparted force, a procedure known as soft-docking. The cable is then retracted to bring the satellites into a hard-dock state. Finally, the mechanism locks in place, maintaining a rigid mechanical connection that will permit fluid transfer and refueling, power and data exchange, and physical component replacement.

Background

The capability to autonomously service spacecraft while on orbit has enormous potential for revolutionizing how spacecraft are designed, fielded, utilized, and operated in the future. The capability to upgrade hardware on existing satellites and to maintain, repair, or refuel others provides flexibility that will be key to maintaining US space dominance. In addition, this flexibility will be critical in ensuring operationally responsive space. Military systems must be responsive to changing requirements even after the systems have been launched. On-orbit servicing and assembly are excellent candidates because satellites could be upgraded or reconfigured in a fraction of the time it would take to design, build, and launch a new satellite.

Awards and Recognition

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Awards and Recognition

Page

AFOSR-Funded Scientist Wins Pioneer Prize

Dr. Stanley Osher, an AFRL Air Force Office of Scientific Research-funded scientist, was awarded the International Congress on Industrial and Applied Mathematics Pioneer Prize for his outstanding contributions to applied mathematics and computational sciences.

AFOSR Analyst Receives One of Germany's Highest Military Honors

Mr. Phil Gibber, a retired Navy captain who is an AFRL Air Force Office of Scientific Research senior international program analyst, earned the Silver Cross of Honor of the Federal Armed Forces for his personal commitment and dedication to the Engineer and Scientist Exchange program between the US and Germany.

Dr. Richard A. Soref Honored as IOP Fellow

Dr. Richard A. Soref, a scientist from the AFRL Sensors Directorate, was named a Fellow of the Institute of Physics (IOP) for his pioneering work in silicon-based photonics and optoelectronics. The AFRL Air Force Office of Scientific Research supported Dr. Soref for more than a decade to lead the research in silicon-based photonics and optoelectronics.

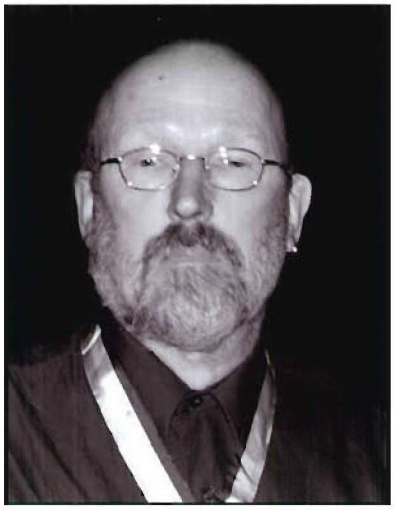
Four AFRL Scientists Honored With Presidential Rank Awards

Dr. Baker, the AFRL Directed Energy Directorate's chief scientist, received the rank of Meritorious Senior Professional for his 33 years of unparalleled achievement in advanced weapons technology.

Dr. Carlson, the AFRL Air Force Office of Scientific Research chief scientist, received the rank of Meritorious Senior Professional for his leadership role in defining the science and technology programs critical to the Air Force of 2020 in a report to Congress.

Dr. Fugate, the AFRL Directed Energy Directorate's senior scientist for atmospheric compensation, received the rank of Distinguished Senior Professional for his research efforts that have enabled revolutionary new military and scientific applications of lasers and optical systems in and through the atmosphere.

Dr. Garscadden, the AFRL Propulsion Directorate's chief scientist, received the rank of Meritorious Senior Professional for his exceptional leadership, innovation, and dedicated research.



AFRL-Funded Professor Honored for His Combustion Theory

Dr. John Buckmaster, an AFRL Air Force Office of Scientific Research–funded aerospace engineer, was awarded the 2004 Zeldovich Medal for his outstanding contributions to combustion theory.

AFRL-Funded Scientist Honored With Dirac Medal

Dr. Vladimir E. Zakharov, an AFRL Air Force Office of Scientific Research–funded scientist, received the prestigious Dirac Medal for his contributions to physics and math.

Drs. Addington, Poggie, and Zweber Announced as AIAA Associate Fellows

Dr. Gregory Addington, Dr. Jonathan Poggie, and Dr. Jeffery Zweber, of the AFRL Air Vehicles Directorate, were announced as American Institute of Aeronautics and Astronautics (AIAA) Associate Fellows for their accomplishments in significant engineering and scientific work, outstanding merit, and outstanding contributions to the arts, sciences, and technology of aeronautics and astronautics.

Dr. Siva Banda Elected to National Academy of Engineering

The National Academy of Engineering elected Dr. Siva Banda, senior scientist and leader of the AFRL Air Vehicles Directorate's Control Science Center of Excellence, as a member for his leadership in the development of multivariable control theory and its applications to an array of military vehicles.

Dr. Roger Kimmel Receives AIAA Outstanding Technical Contribution Award

The Dayton-Cincinnati Section of the American Institute of Aeronautics and Astronautics (AIAA) presented Dr. Roger Kimmel, a senior aerospace engineer at the AFRL Air Vehicles Directorate, with the Outstanding Technical Contribution Award for designing plasma actuators that may one day control high-speed air vehicles.

Ms. Alyson Melo Earns ASME Young Engineer Award

The Dayton Area Chapter of the American Society of Mechanical Engineers (ASME) awarded Ms. Alyson Melo, an aerospace engineer at the AFRL Air Vehicles Directorate, with its Young Engineer Award for her ASME participation, professional attainments, educational progress, and community service.

Dr. Stephen Clay Receives the Perkins In-House Engineering Award

The AFRL Air Vehicles Directorate awarded Dr. Stephen Clay the Dr. Courtland D. Perkins In-House Engineering Award for developing a new method to internally reinforce adhesively bonded metal to composite joints.

AFRL Team Wins AIAA Outstanding Technical Contribution Award

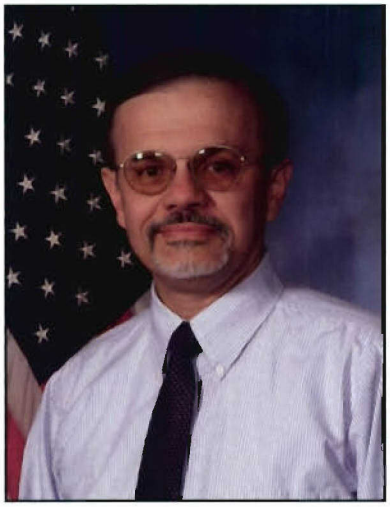
The Dayton-Cincinnati Section of the American Institute of Aeronautics and Astronautics (AIAA) presented Dr. David Doman and Dr. Michael Oppenheimer, both of the AFRL Air Vehicles Directorate, with the Outstanding Technical Contribution Award for their significant contributions to the field of integrated adaptive guidance and control.

Drs. Doman and Oppenheimer Receive the General Benjamin D. Foulois Award

Dr. David Doman and Dr. Michael Oppenheimer, both of the AFRL Air Vehicles Directorate, received the General Benjamin D. Foulois Award for their team effort in developing a control system that helps unmanned reusable launch vehicles compensate for control system failure, damage, or changing conditions in the manner of a human pilot.

Dr. Carl Tilmann Receives AIAA Outstanding Management Contribution Award

The Dayton-Cincinnati Section of the American Institute of Aeronautics and Astronautics (AIAA) presented Dr. Carl Tilmann, of the AFRL Air Vehicles Directorate, with the Outstanding Management Contribution Award for his leadership in multiple complex research efforts in applied flow control.



Mr. Vince Miller Honored As ASME Fellow

The American Society of Mechanical Engineers (ASME) selected Mr. Vince Miller, a senior aerospace engineer at the AFRL Air Vehicles Directorate, as an ASME Fellow for his leadership, technical contributions, and research in aircraft noise transmission.

Mr. Terry Duncan Receives Arthur S. Flemming Award

Mr. Terry Duncan, chief engineer at the AFRL Directed Energy Directorate's Starfire Optical Range, was awarded the Arthur S. Flemming Award, Applied Science category, for outstanding federal service.

Master Sergeant Steven Tuss Receives IDEA Award

Master Sergeant Steven Tuss, a technician with the AFRL Directed Energy Directorate's Laser Effects Research Branch, submitted through the Innovative Development Through Employee Awareness (IDEA) program an idea to improve his work area and received a $10,000 award for his efforts. Using his method, technicians avoid the potentially hazardous environment created by chemical laser operations.

Dr. Robert Q. Fugate Receives Air Force Distinguished Presidential Rank Award

Dr. Robert Q. Fugate, of the AFRL Directed Energy Directorate's Beam Control Division, received the Presidential Rank Award in the Distinguished Senior Professional category for his strong leadership, professionalism and achievements.

Dr. William L. Baker Receives Distinguished Presidential Rank Award

Dr. William L. Baker, the chief scientist of the AFRL Directed Energy Directorate, received the Presidential Rank Award in the Meritorious Senior Professional category for his contributions to the organization throughout his career, as well as his contributions to the development of advanced weapons systems for the nation's defense.

AFRL Names Six New Fellows

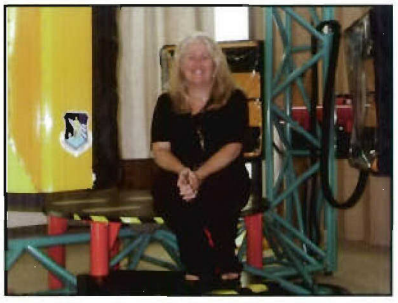
AFRL recognized and rewarded six AFRL scientists and engineers as Fellows for their achievements and technical excellence supporting our nation's air and space forces. The honorees are as follows: Dr. Alok Das (top left), AFRL Space Vehicles Directorate; Dr. Craig Denman (top right), AFRL Directed Energy Directorate; Dr. Nelson Forster (middle left), AFRL Propulsion Directorate; Dr. Gregory Ginet (middle right), AFRL Space Vehicles Directorate; Mr. Larry Perkins (bottom left), AFRL Materials and Manufacturing Directorate, and Dr. Edward Watson (bottom right), AFRL Sensors Directorate.

Dr. Mark Draper Wins Air Force Research and Development Award

Dr. Mark Draper, a major in the Air Force Reserves working with the AFRL Human Effectiveness Directorate, received the Air Force Research and Development Award for his pioneering work on unmanned air vehicle ground control system interfaces.

Dr. Daniel W. Repperger Named IEEE Chair of Ohio

Dr. Daniel W. Repperger, from the AFRL Human Effectiveness Directorate, earned a key leadership role within the Institute of Electrical and Electronics Engineers (IEEE) at the state level.



Technology Showcased at Winter Olympics Leads to Dr. Kathleen Robinette's Excellence Award for Noted Researcher

Dr. Kathleen Robinette, director of the AFRL Human Effectiveness Directorate's Computerized Anthropometric Research and Design Laboratory, was awarded the Air Force Materiel Command Public Affairs Director's Excellence Award for Special Achievement for her outstanding support during the 2002 Winter Olympics in Utah.

Dr. Gregory F. Zehner Receives SAFE Award for Outstanding Individual Achievement

Dr. Gregory F. Zehner, of the AFRL Human Effectiveness Directorate, received the Safety Award for Excellence (SAFE) Association 2003 Outstanding Individual Achievement Award for his development of a practical, multivariate, anthropometric analysis for crewstation design.

Dr. Andrew A. Pilmanis Receives ASMA's Sidney D. Leverett Award for Outstanding Research in Altitude Studies

The Aerospace Medical Association (AsMA) selected Dr. Andrew A. Pilmanis, of AFRL's Propulsion Directorate, as the recipient of this year's Sidney D. Leverett Award for his significant work in altitude decompression sickness research and his publication, "Effect of Repeated Altitude Exposure on the Incidence of Decompression Sickness."

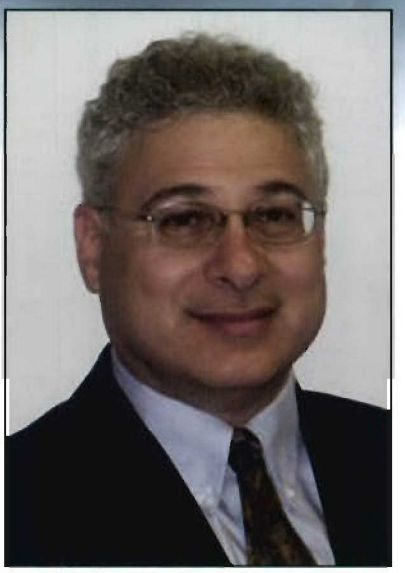
JSF Research Team Earns SAFE Award

The Joint Strike Fighter (JSF) Head Case Research Team received the 2003 Safety Award for Excellence (SAFE) Award for team achievement. Team members—Messrs. Dan Adams, Chris Albery, James Barnaba, Mark Boehmer, John Buhrman, Steve Goldner, Alva Karl, Thanh Nghi, Jeffery Nichols, Glenn Paskoff, Joseph Pellettiere, John Plaga, Glenn Thomas , and Ms. Kathleen Robinette—researched, defined, and produced mannequin heads to use during dynamic testing, which will establish the safe boundaries for the JSF helmet-mounted device and helmet.

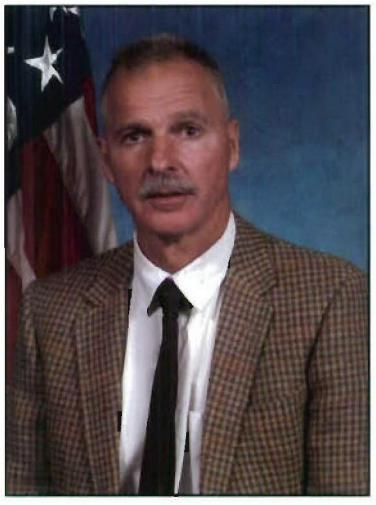
AFRL Team Advances Military Applications of Speech Recognition Technology

Mr. Mark H. Draper and Mr. David T. Williamson, both of the AFRL Human Effectiveness Directorate, and Mr. Timothy P. Barry, from SYTRONICS, Inc., won the Gary Poock Best Paper Award during the AVIOS~SpeechTEK 2004 Awards conference for their paper "Commercial Speech Recognition Technology in the Military Domain: Results of Two Recent Research Efforts."

Dr. Alan R. Pinkus Wins ASTM International Award of Merit



Dr. Alan R. Pinkus, a senior engineering research psychologist from the AFRL Human Effectiveness Directorate, received the American Society for Testing and Materials (ASTM) International Award of Merit for developing, publishing, and internationally coordinating standardized test methods that optimize vision through aerospace transparencies.



Dr. Ulf Balldin Receives AsMA's Arnold D. Tuttle Award for Original Research

The Aerospace Medical Association (AsMA) selected Dr. Ulf Balldin for the Arnold D. Tuttle Award for his research and subsequent paper entitled "Endurance and Performance During Multiple Intense High +Gz Exposures With Effective Anti-G Protection."

Dr. Kumar V. Jata Earns Air Force Basic Research Award Honorable Mention

Dr. Kumar V. Jata, of the AFRL Materials and Manufacturing Directorate, received an Air Force Basic Research Award Honorable Mention for outstanding contributions to the development of a fundamental understanding of the effects of severe plastic deformation on microstructure evolution and implications to static and cyclic mechanical behavior in high-strength aluminum and titanium alloys for aircraft and space access.

AFRL Scientists Earn Air Force Outstanding Scientist Awards

Captain Wynn S. Sanders, Dr. Richard A. Vaia, and Major Scott F. Walter, all with the AFRL Materials and Manufacturing Directorate, each earned the Air Force Outstanding Scientist Award in recognition of individual achievements.

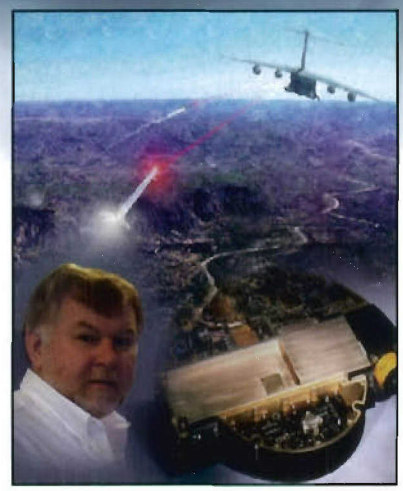
Dr. Darnell E. Diggs Named 2004 Black Engineer of the Year/Most Promising Scientist in Government

Dr. Darnell E. Diggs, a physicist with the AFRL Materials and Manufacturing Directorate, was selected the 2004 Black Engineer of the Year in the category Most Promising Scientist in Government for his ability, professionalism, and dedication.

AFRL Experts Earn Star Team Award for Research Excellence

A team of researchers at the AFRL Materials and Manufacturing Directorate received an AFRL Air Force Office of Scientific Research Star Team Award for outstanding contributions to science, the Air Force, and national defense.

Mr. Ray Linville Receives Top Air Force Honors



The Air Force awarded Mr. Ray Linville the Air Force Science and Engineering Award for Manufacturing. Mr. Linville, an engineer with the AFRL Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division, received the award for his outstanding abilities defining, leading, and managing programs in support of laser eye protection and the Viper™ laser.

AFRL Leads Team to Two Top DoD Awards

AFRL captured two prestigious Department of Defense (DoD) awards, the 5th annual Defense Technology Achievement Award and the Small Business Team Award for Defense Manufacturing Excellence. Both awards were presented for the success of laser shock peening.

Mr. Walter Zimmer Part of Award-Winning Team

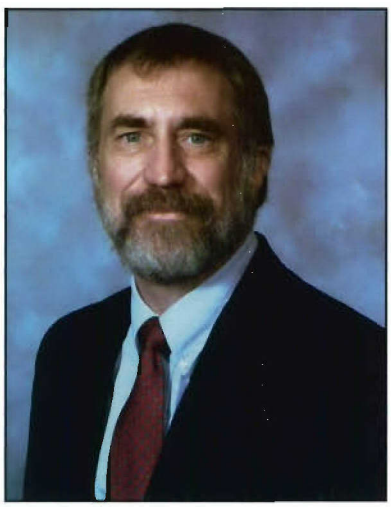
Mr. Walter Zimmer, an engineer with the AFRL Materials and Manufacturing Directorate's Manufacturing Technology Division, received the 5th annual Defense Manufacturing Technology Achievement Award as a member of the laser additive manufacturing initiative team.

AFRL Team Earns Fourth Consecutive Star Team Award

The AFRL Materials and Manufacturing Directorate's Characterization of Electronic Device Materials Research Team, a team of 20 scientists and engineers, received its fourth consecutive AFRL Air Force Office of Scientific Research Star Team Award for outstanding contributions to science, the Air Force, and national defense.

Dr. Timothy J. Bunning Earns ASC Award for Outstanding Achievement

Dr. Timothy J. Bunning, a polymer physicist at the AFRL Materials and Manufacturing Directorate, received the 2004 Outstanding Engineers and Scientists Award from the Affiliate Societies Council (ASC) of Dayton, Ohio.



Dr. Barry L. Farmer Receives ASC Outstanding Achievement Award

Dr. Barry L. Farmer, the chief scientist of the AFRL Materials and Manufacturing Directorate, received the prestigious 2004 Outstanding Engineers and Scientists Award from the 15,000-member Affiliate Societies Council (ASC) of Dayton, Ohio.

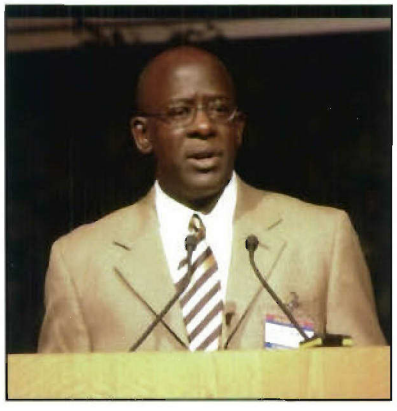
Major Timothy M. Schulteis Earns AFMC's General James Ferguson Engineering Award

Major Timothy M. Schulteis, the technical director of the AFRL Materials and Manufacturing Directorate's Robotics Research Group, was awarded the Air Force Materiel Command's (AFMC) General James Ferguson Engineering Award.

Dr. John F. Maguire Awarded British Academia's Highest Honor

Dr. John F. Maguire, chief of the AFRL Materials and Manufacturing Directorate's Nonmetallic Materials Division Polymer Branch, received the United Kingdom's highest academic degree, Doctor of Science for his pioneering work in materials characterization and computer simulation and modeling.

Mr. James A. Neely Receives Air Force Honors



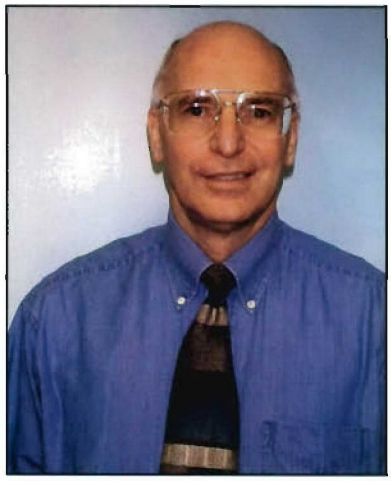
Mr. James A. Neely, of the AFRL Materials and Manufacturing Directorate's Manufacturing Technology (ManTech) Division, received the Air Force Exemplary Civilian Service Award for his outstanding leadership and management skills.

Dr. Bob Sierakowski Named Composite Award Winner

The American Society for Composites selected Dr. Bob Sierakowski, the chief scientist of the AFRL Munitions Directorate, as the winner of the Award in Composites for 2003 for his long-term contributions to the society.

Dr. Melvyn Roquemore Wins Prestigious AIAA Award

Dr. Melvyn Roquemore, senior combustion scientist in the AFRL Propulsion Directorate, was named an American Institute of Aeronautics and Astronautics (AIAA) Propellants and Combustion Award winner for his many groundbreaking achievements during a distinguished 38-year Air Force career.



Mr. Peter T. Lamm Receives SAE Medal for Technical Paper

Mr. Peter T. Lamm, a project engineer in the AFRL Propulsion Directorate, received the Society of Automotive Engineers (SAE) Charles M. Manly Memorial Medal for his technical paper "Analysis and Simulation of a UAV [unmanned air vehicle] Power System."

Major Mona D. Wheeler Awarded Technology Honors

Major Mona D. Wheeler, of the AFRL Propulsion Directorate, received the Emerald Honor for Professional Achievement at the 3rd annual Women of Color Research Sciences and Technology Awards Conference for her work as a project manager, chemist, and laboratory chief.

Dr. Rengasamy Ponnappan Named ASME Fellow

Dr. Rengasamy Ponnappan, of the AFRL Propulsion Directorate, was named an American Society of Mechanical Engineers (ASME) Fellow.

Dr. Ashwani Vij Nominated for Air Force Basic Research Honor

Dr. Ashwani Vij, of the AFRL Propulsion Directorate, was nominated for the Air Force Basic Research Award. The nomination was based on his discovery of the key chemical species N_5^- in the engineering area of polynitrogen chemistry.

Ms. Monica Jacinto Receives AIAA Award for IMWG Effort

The West Coast Region American Institute of Aeronautics and Astronautics (AIAA) recognized Ms. Monica Jacinto, an AFRL Materials and Manufacturing Directorate contractor with Boeing-Rocketdyne, as Engineer of the Year for her success in developing materials for rocket engines. The AFRL Propulsion Directorate funded the Integrated High-Payoff Rocket Propulsion Technology Materials Working Group (IMWG) development project for Ms. Jacinto.

Mr. Daron Bromaghim and Dr. J. Michael Fife Receive FLC Excellence in Technology Transfer Award

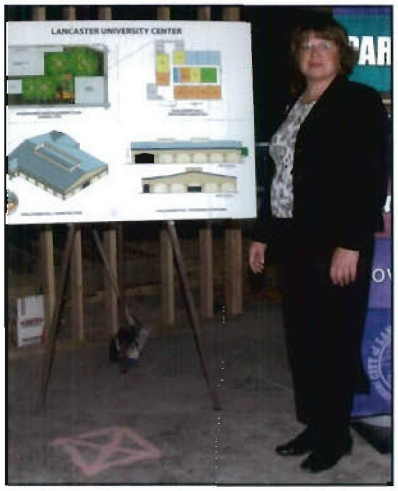
The Federal Laboratory Consortium (FLC) honored Mr. Daron Bromaghim and Dr. J. Michael Fife, of the AFRL Propulsion Directorate, with the Excellence in Technology Transfer Award for their research and technology transfer efforts on innovative electric propulsion space technology.

Mr. Jeffrey Thornburg Receives NASA Leadership Award

The AFRL Propulsion Directorate's test unit at the National Aeronautics and Space Administration's (NASA) John C. Stennis Space Center honored Mr. Jeffrey Thornburg, the Integrated Powerhead Demonstration's Air Force program manager, for his outstanding program leadership at the NASA center.

Dr. James Gord and Dr. Robert Hancock Receive Prestigious Award

The *Dayton Business Journal* selected Dr. James Gord and Dr. Robert Hancock, both of the AFRL Propulsion Directorate, as recipients of the Dayton business community's 7th annual 40 Under 40 award for their business, community leadership, and career accomplishments.

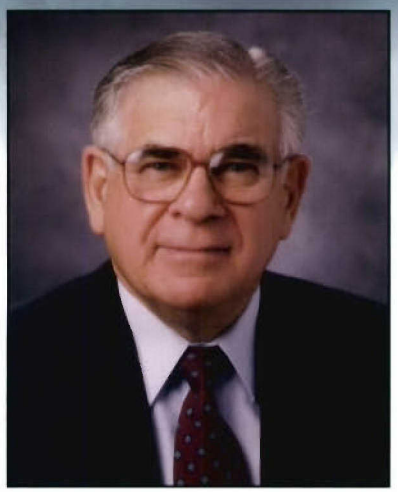


Dr. J. Stebbins Shelley Educates Future Engineers

Dr. J. Stebbins Shelley, of the AFRL Propulsion Directorate, was named the mechanical engineering professor for the new Lancaster University Center, Lancaster, California, through an educational partnership agreement.

Pentagon Honors Mr. Daniel A. Dickey and Mr. Ernest C. Simpson

Two former AFRL Propulsion Directorate employees, Mr. Daniel A. Dickey and Mr. Ernest C. Simpson, were selected as inaugural members of the Career Civil Service Exemplars.



Former AFRL Director Receives Award for Continued Accomplishments in Propulsion Systems Development

The American Institute of Aeronautics and Astronautics awarded Dr. Edward T. (Tom) Curran, former AFRL Propulsion Directorate director, the Air Breathing Propulsion Award. This award recognizes Dr. Curran for his distinguished career achievements.

Mr. Mark Speed Wins AOC Award for Communications

Mr. Mark Speed, a Ball Aerospace and Technologies Corporation engineer working in the AFRL Sensors Directorate, received the Association of Old Crows (AOC) Communication Award for his dedication, technical expertise, and initiative displayed during the development of a highly flexible Link-16 simulation software package.

Mr. P. Aaron Linn Receives AOC Award for Research and Development

Mr. P. Aaron Linn, of the AFRL Sensors Directorate, received the Association of Old Crows (AOC) Research and Development Award for his achievement in the research and development of new electronic warfare technology.

Mr. Ronald Kaehr Receives Exemplary Civilian Award

Mr. Ronald Kaehr was awarded the Exemplary Civilian Service Award in recognition for his distinguished service as senior strategic planner for the AFRL Sensors Directorate.

Mr. Louis Chan Receives AOC Award for Modeling and Simulation

Mr. Louis Chan, of the AFRL Sensors Directorate, received the Association of Old Crows (AOC) Modeling and Simulation (M&S) Award for his outstanding achievements in the development of M&S relating to electronic warfare.

Dr. Donald W. Hanson Honored as IEEE Fellow

The Institute of Electrical and Electronic Engineers (IEEE) named Dr. Donald W. Hanson, director of the AFRL Sensors Directorate a 2004 Fellow for technical leadership in the development and realization of sensors science and technology.

Mr. Joseph Koesters Wins Prestigious Award

Mr. Joseph R. Koesters, a senior AFRL Sensors Directorate scientist, received the Bill Goodell Memorial Award for Distinguished Service for his outstanding contributions and dedicated service to the infrared countermeasures community.

Dr. Mark E. Davis Receives Exemplary Civilian Service Award

Dr. Mark E. Davis, a chief engineer for the AFRL Sensors Directorate's Space-Based Radar program, was awarded the Exemplary Civilian Service Award in recognition for his outstanding technical and programmatic leadership.

AFRL Space Vehicles Team Earns AIAA Award

The American Institute of Aeronautics and Astronautics (AIAA) presented the Space Systems Technical Team Award to the AFRL Space Vehicles Directorate/ Boeing XSS 10 team for their contributions toward microsatellite technology.

Dr. Lawrence Robertson Named AIAA Associate Fellow

The American Institute of Aeronautics and Astronautics (AIAA) named Dr. Lawrence "Robbie" Robertson, of the AFRL Space Vehicles Directorate, an Associate Fellow for 2003 for making notable contributions to the technology of aeronautics or astronautics.

Dr. Richard Scott Erwin Named Albuquerque IEEE Outstanding Young Engineer

The Albuquerque Section of the Institute of Electrical and Electronics Engineers (IEEE) named senior member Dr. Richard Scott Erwin, technical advisor for the AFRL Space Vehicles Directorate, as Outstanding Young Engineer for 2004. The association recognized Dr. Erwin's outstanding contributions to spacecraft component technology research that includes spacecraft controls, vibro-acoustics, structures, optical systems, and space power systems.